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Assessment of Bridges in Eastern Montana to Identify Active Season Bat Roosts

Rachel Hopkins
Carroll College, Helena, MT

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This thesis for honors recognition has been approved for the

Department of Life and Environmental Sciences

Grant Hunt — 4/19/18
Director — Date

[signature] — 4/25/18
Reader — Date

Ryan Harris — 4/19/18
Reader — Date

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Submitted in partial fulfillment of the requirements for graduation with honors from the department of Life and Environmental Sciences at Carroll College, Helena, MT

Rachel Hopkins

Carroll College, Helena, MT

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This thesis for honors recognition has been approved for the Department of Life and Environmental Sciences by:

Dr. Grant Hokit, director, Senior Research Associate and Professor of Biology

Dr. Ryan Hallows, Associate Professor of Spanish and Latin American Studies, Department of Languages and Literature

Dr. Kyle Strode, Professor of Chemistry

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Abstract

Bats fulfill important niches in the ecosystems they occupy and control insect populations that are agricultural pests. Bat species across North America face several significant threats including habitat degradation/roost disturbance, wind turbine-related deaths, and White-Nose Syndrome (WNS). In Montana, bat roost information has been lacking in the nine eastern counties where Northern Myotis (*Myotis septentrionalis*) is listed as Threatened, as well as a large number of additional central and eastern Montana counties. To identify active season roosts across these regions, I surveyed bridges for bat use. From the surveys, I established baseline knowledge about bat roosting preferences and the locations of active roost sites to monitor, which can be used to better inform conservation efforts. Survey data were collected from bridges in nine counties in Eastern Montana, as well as from bridges in eight counties in central Montana. Bridges surveyed were classified by roost type (day, night, maternity, none). Structural materials, surrounding habitat characteristics, and other attributes were recorded. Night roosts were the most common roost type, concrete bridges were the most used bridge type, and maternity roosts were only found in wooden bridges with ideal crevices. Results which show widespread use of concrete bridges as roosts, and the importance of ideal crevices for day and maternity roosting bats, are consistent with previous studies in western and central Montana. Ideal crevices are an important structural characteristic for bridge roosting bats, which, when implemented in bridge design, provide suitable habitat in the face of increasing urbanization and human disturbance.

Introduction

Bats are keystone species, fulfilling important niches as insect-eaters and pollinators (Kunz et al., 2011). Insectivorous bats provide an important service in keeping insect populations in check, which benefits not only the ecosystems they occupy but also human interests, such as the agriculture industry (Brown & Berry, 2005; Whitaker & Weeks, 2001; Boyles et al., 2011). For example, big brown bats, *Eptesicus fuscus*, are known to eat insects that create problems for forest or agricultural success (Brown & Berry, 2005). Using the data collected by Whitaker (1995), it can be estimated that just one colony (an average of 150 bats) of this same species in Indiana would consume approximately 1.3 million agricultural pests each year (Boyles et al., 2011). As an example, this includes the consumption of approximately 600,000 cucumber beetles which subsequently would lead to the prevention of 33 million rootworms (Whitaker, 1995). Boyles et al. (2011) estimated the monetary value of bats to be between $3.7 billion and $53 billion annually for the agriculture industry in the United States.

Unfortunately, bats are facing several significant threats, including, white-nose syndrome, (WNS), wind turbine-related deaths, and habitat loss and degradation (Boyles et al., 2011; Turner et al., 2011; Agosta, 2002; McCracken, 1989). One of the most significant threats bats face is white-nose syndrome, which most directly impacts cave-dwelling, hibernating bats, such as species of *Myotis* (Meteyer et al., 2011). WNS is an infectious disease caused by the fungus, *Pseudogymnoascus destructans*, which infects hibernating bats, causing physiological changes such as the characteristic white hyphae on the muzzle and wings (Boyles et al., 2011; Meteyer et al., 2011). Usually the infection is fatal (Boyles et al., 2011). A five-year assessment of mortality and spread of WNS found that in 42 sites, the number of hibernating bats decreased by 88.5% from 412,340 to 49,579 (Turner et al., 2011). Other affected areas had population decreases of up to 98% (Turner et al., 2011). WNS is responsible for the mortality of an estimated 5,000,000 bats in the Eastern United States and Canada, however, new research has documented some resistance to the fungus from *E. fuscus* in certain areas (Frank et al, 2014). Additionally, Langwig et al. (2016) collected data on nine different survey sites, classifying bats into seven different "load classes" according to quantity of fungus present. They found that those bats who persisted were exhibiting resistance in the form of reduced growth of the fungus. Although signs of resistance are promising, WNS still remains a devastating threat that must be addressed.

Habitat degradation and roost disturbance caused by humans also affect bat species (Agosta 2002; McCracken, 1989, Kunz et al., 2007). Cave-dwelling and rock roosting bats are especially vulnerable to human impact (Agosta, 2002). Human disturbance could include commercial cave development, quarrying, and even shining light on hibernating bats (McCracken, 1989). Disturbances of maternity colonies can have devastating effects, causing bats to abandon roost sites (MacCracken, 1989). This in turn might cause death of the young, since female bats move to less ideal roost sites, and there are decreases in thermal energy benefits for the bats that remain (McCracken, 1989). Wind turbines also have negative impacts on bat species, but more directly affect tree-roosting bats (Boyles et al., 2011; Kunz et al., 2007).

Given the above concerns about reductions in numbers, it is of vital importance to learn more about bats in order to inform conservation efforts. For many species of bats, little is known about roost preference and habitat selection (Fenton, 1997). However, depending on the species of bat, roost sites could include trees, bridges, rock crevices, and buildings (Hendricks et al., 2005). Bridges can provide structural characteristics such as crevices or sheltered areas that bats may find suitable for roosts (Harvey et al., 2004). Additionally, bridges often cross water which could be a preferable habitat feature, especially for bat species that forage over water (Harvey et al., 2004). There are many factors that go into how an individual bat chooses a roost, for example certain bats might prefer roosts closer to still water (Brooks & Ford, 2005). However, much remains unknown about roost preferences and about what might make a roost location desirable.

Only certain bat species are known or suspected to use bridges for roost sites, and bridge selection likely varies greatly among species, and even among individual bats (Harvey et al., 2004; Hendricks et al., 2005). Relatively little research has been completed in regards to the use of bridges as roost sites, with Hendricks et al. (2005) being one of the first comprehensive surveying efforts in Montana. In Billings, Montana, Hendricks, et al. (2005) surveyed bat use of highway structures from 2003-2004 for the department of transportation and found 66 of the 130 structures were night roosting sites, 12 were day roosting, and that use of bridges by bats was overall unrelated to the surrounding landscape features. They identified four species of bats: Big Brown Bats (*Eptesicus fuscus*) in 10 structures, Hoary Bats (*Lasiurus cinereas*) in one structure, Little Brown Myotis Bats (*Myotis lucifugus*) in two, and Western Small-footed Myotis Bats (*Myotis ciliolabrum*), in two. Bats appeared to prefer concrete structures to steel or wood. Similar results were found in the bridge surveys conducted by Whittle (2015) in western Montana. Night roosts accounted for the majority of bat roosts (45.9% of total bridges surveyed), with only 2.7% attributed to day roosts. Additionally, bridges with concrete under decking were preferred over steel or wood (Whittle, 2015).

The purpose of this research is to quantify and qualify bat use of bridges in Eastern Montana, in the counties of Carter, Custer, Dawson, Fallon, Prairie, Powder River, Richland, Roosevelt, and Wibaux, in order to gain information in an area which lacks regional roost surveys. Additionally, surveys were completed in eight counties in central Montana: Judith Basin, Fergus, Petroleum, Broadwater, Meagher, Wheatland, Golden Valley, and Musselshell. The data collected from this study area were compared to data from other study areas in order to provide a more complete picture of bridge-roosting bats throughout the state of Montana. This study provides baseline data to help assess the impacts of WNS. To fulfill these goals, I collected data on bat use of bridges, including roost type (maternity, day, or night roost), structural details of the bridges surveyed (concrete, steel, wood, ideal crevices), and surrounding vegetation cover and habitat characteristics (type of forest, presence of water, landscape, slope). The data collected, along with the analysis completed from the data, were provided to state and federal agencies, such as the Montana Natural Heritage Program, in order to help inform the management of bats and their habitat in Montana, especially in regard to the threat of WNS. Based on the research that has already been completed on this topic, I hypothesize that bridges with concrete decking material will be preferred roost sites over bridges with wood or steel decking. Additionally, I hypothesize that the presence of ideal crevices is an important factor in determining whether there are day or maternity roosts.

Methods

The study area for this project includes the counties of Carter, Custer, Dawson, Fallon, Powder River, Prairie, Richland, Roosevelt, and Wibaux. This area was chosen because there is a lack of adequate survey information and if WNS were to spread from North and South Dakota, this area would be one of the first to be affected. Therefore, baseline data are needed in order to determine where to conduct surveillance on bat species in the area. After the majority of bridges in this area were surveyed, additional surveys were completed for bridges on or nearby route 200, and highway 12, within the counties: Judith Basin, Fergus, Petroleum, Broadwater, Meagher, Wheatland, Golden Valley, and Musselshell. This area was selected because it also lacked roost surveys. However, less bridges were surveyed within these counties, given time constraints. Within these study areas, Geographic Information System (GIS) maps of the state of Montana indicated the locations of bridges across the study area. Once selected, surveys were performed during daylight hours throughout the months of June, July, and August. The initial sites were surveyed in June and July and those sites with bats in a day or maternity roost site were revisited in late July and August to determine the duration of bat (sps.) use and the presence of maternity colonies.

The survey process involved inspecting the undersides of bridges for signs of bat use, such as urine stains or guano. Once I inspected the bridge, I classified it by roost type. Roost type could be: day roost (bat(s) present), maternity roost (young present), night roost (droppings or urine stains), or no roost (no bat sign/presence). During the surveys, I used a custom built 6,000+ lumens flashlight to illuminate dark crevices, as well as binoculars to scan for bats. I took photographs of the survey sites and recorded the following: the number and species of bats present, the type of roost, and type of roost features present. A complete data sheet is provided in appendix A.

If a night roost was found, it was rated according to the following criteria:

- 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 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.

If ideal crevices (defined as crevices 0.64-3.18 centimeters wide, and greater than 10 centimeters deep) were present, and unable to be examined by the naked eye, I used a video-recording DeWalt DCT 9mm Inspection Camera (DeWalt Industrial Tool Co. Baltimore, MD) extended on a telescoping pole to look back into the crevice. If possible, individuals were identified to genus and species, by conducting visual inspection with the help of several resources, *Mammals of Montana* (Foresman 2012), and *Bats of the Rocky Mountain West* (Adams 2003). At maternity and day roosting colonies, the temperature of the roost substrate was recorded using a Cason CA 380 infrared thermometer sensor (Cason Electronic Holdings Company, Hong Kong, China). At each bridge survey site, data were also recorded in reference to the surrounding habitat characteristics (residential, agricultural, commercial, woodland, etc.), the structure and design of the bridge, the roost substrate, and conditions beneath the roost such as the presence or absence of water.

Once the data were collected from the surveys, I used statistical analyses to determine how type of bat use varies by bridge structural characteristics. To explore the relations between bridge type and bat use I used several contingency tests, to compare bat roosts with bridge material and ideal crevices. Additionally, I used ArcGIS to make a map of my data and performed spatial analysis to examine differences in bat roosting preferences across the state of Montana. The guano samples I collected were sent to the United States Forest Service, who in conjunction with the National Genomics Center for Wildlife and Fish Conservation, performed DNA analysis by testing at two mitochondrial DNA regions known to be useful in identifying bat species. They provided the results in a report sent to the Montana Natural Heritage Program (Uecker, et al., 2018) which are included in the results section.

Results

Several different statistical analyses were used to analyze the data. First, I performed contingency analysis comparing the presence or absence of bats with the decking material of the bridge. I found a chi-square statistic of 93.21 and a p value of < 0.0001. Therefore, there is a significant association between different decking material and bat use, Fig. 1.

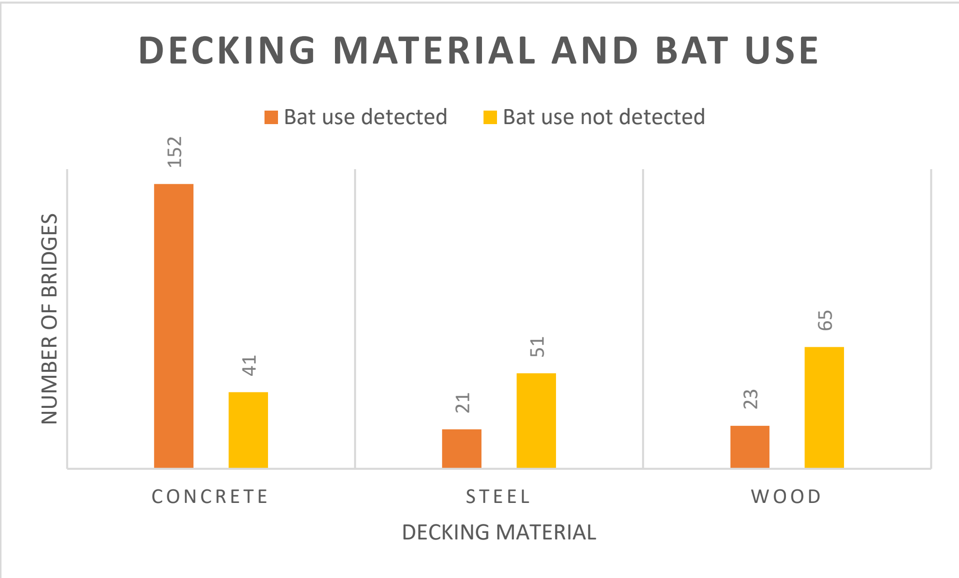

Figure 1: Total number of bridges surveyed with bat use detected and not detected for each type of decking material (concrete, steel, wood). Bat use detected means the bridge had evidence of bat use of any roost type classification (day, night, maternity). Bat use not detected means no bats were found at the bridge, and no evidence of use as a roost was found either (guano, urine stains).

Concrete bridges had the highest bat use of any decking material (78% of all bridges with bat use detected), and steel bridges had the lowest bat use. Concrete bridges were also the most numerous type of bridge that was surveyed, and steel bridges were the least numerous. For bridges with concrete decking, there were more that had bat use detected than not detected. For the other two decking material types, there were more bridges with bat use not detected than detected. This indicates the importance of concrete bridges as a bat roost.

In addition to performing statistical analysis of decking material and bat use, I also performed analyses to examine how decking material and roost type (day, night, maternity) interacted. First, I performed contingency analysis and got a test statistic of 79.43 and a p value of <0.0001. I also performed a G-statistic analysis, since there are two cells with a zero value, and contingency analysis can often be skewed by zero values. The G-statistic I calculated was 52.214. The p value was <0.0001. This indicates that the data are not distributed evenly. There is a significant interaction between decking material and roost type, Fig 2.

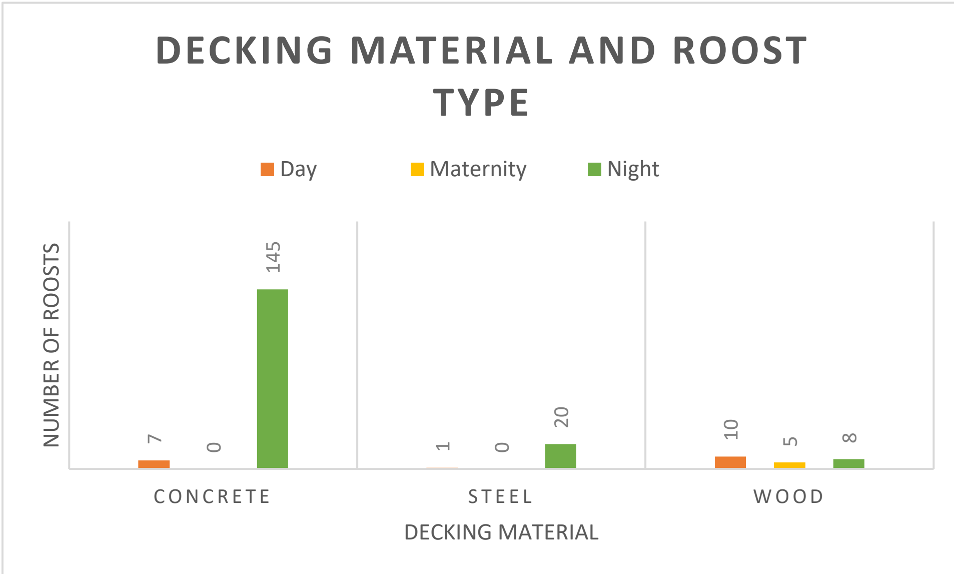

Figure 2: Total number of each type of bat roost present in each type of bridge decking material. Roost type, "day" roost means at least one bat was found during the survey, "night" roost means guano and/or urine stains were found, and "maternity" roost means there was at least one maternity colony of bats found (presence of pups).

Maternity roosts were found only in bridges with wood decking, while night roosts were found in each type of bridge decking material (mostly in concrete), and day roosts were found mostly in concrete and wood. The data suggest maternity roost preference for wooden bridges, night roost preference for concrete bridges, and general preference against steel bridges when compared to the other two decking material types.

Next, I looked at how the presence or absence of ideal crevices affected bridge use by bats. I performed another contingency analysis and got a chi square statistic of 2.580, with a p value of 0.108. Therefore, the data are not distributed significantly differently than would be expected if ideal crevices did not have an effect on bat use. Fig. 3.

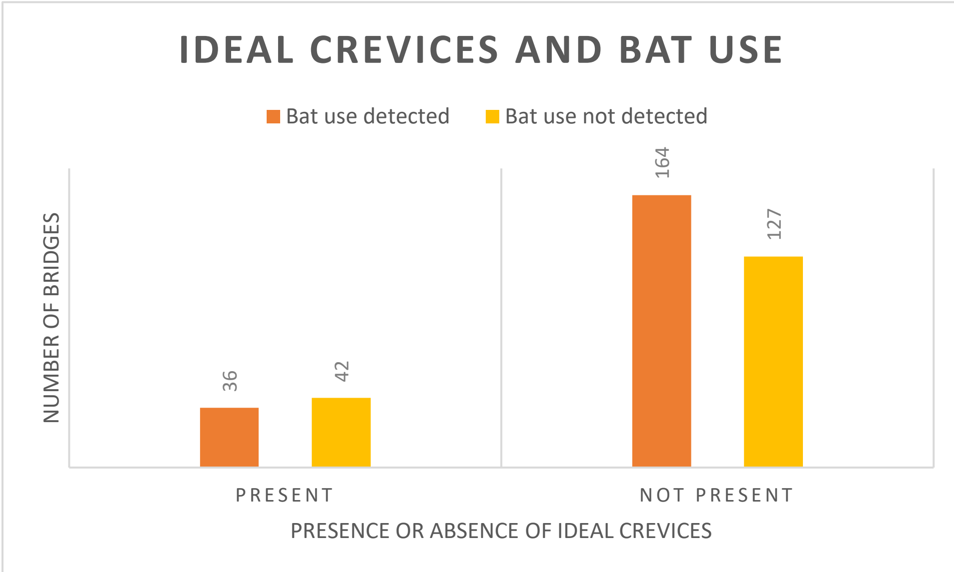

Figure 3: Totals shown for the number of bridges with and without ideal crevices, with bat use detected and not detected. Ideal crevices are defined as crevices underneath the bridge, deep and narrow (usually >4cm. deep).

Although the statistical analysis revealed no significant interaction between the presence or absence of ideal crevices and the detection or not of bats, it is worth noting that there were more bridges without ideal crevices than with them (79% of total bridges surveyed had no ideal crevices). Next, I compared roost type (day, maternity, night) with the presence or absence of ideal crevices to see if there was a significant interaction between these two variables. I performed a contingency analysis and got a statistic of 89.92, and a G-statistic test (there was a zero value for one cell) and got a statistic of 69.43, with p values for both being <0.0001. This indicates that there is a significant interaction between the presence or absence of ideal crevices, and roost type of bats, Fig. 4.

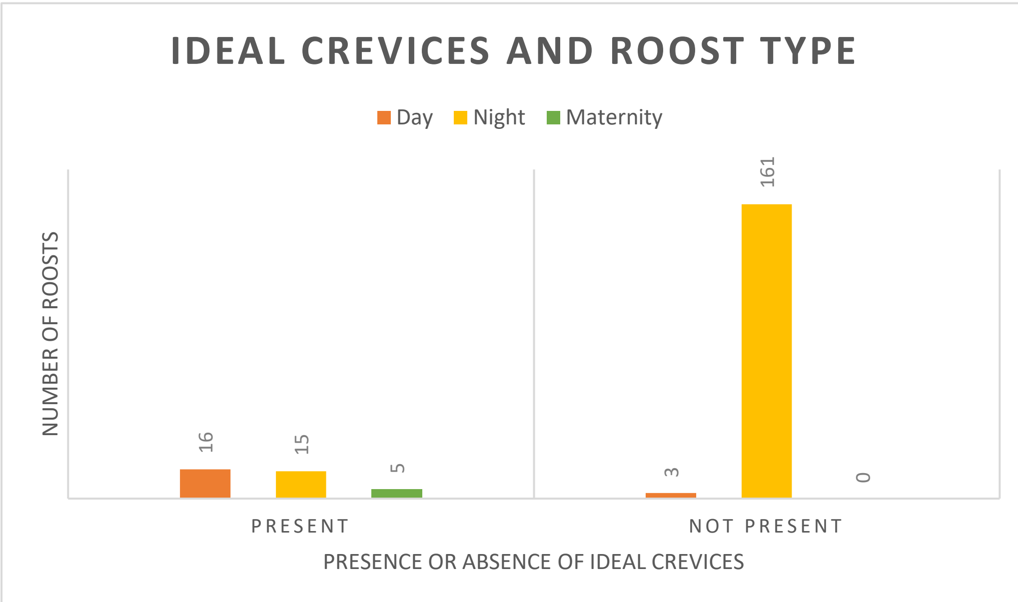

Figure 4: The number of roosts in bridges with and without ideal crevices for each roost type (day, night, maternity).

Since there were no maternity roosts found in bridges without ideal crevices, this suggests that the presence of these crevices is essential for maternity roosts. Day roosts were only present in three bridges that did not have ideal crevices, indicating that these crevices are also important for day roosts. Night roosts were found in large numbers in bridges without ideal crevices, suggesting that the presence of these crevices is not necessary for night roosting bats. Night roosts were the most numerous type of roost (88%).

In addition to performing these analyses on my own data, I acquired data from the Montana Natural Heritage Program for bridges surveyed in western Montana. I compared the decking material by roost type between the ecoregions of my data and western Montana data. Below, are the data for the western region (Fig. 5). For the other regions see Fig. 1.

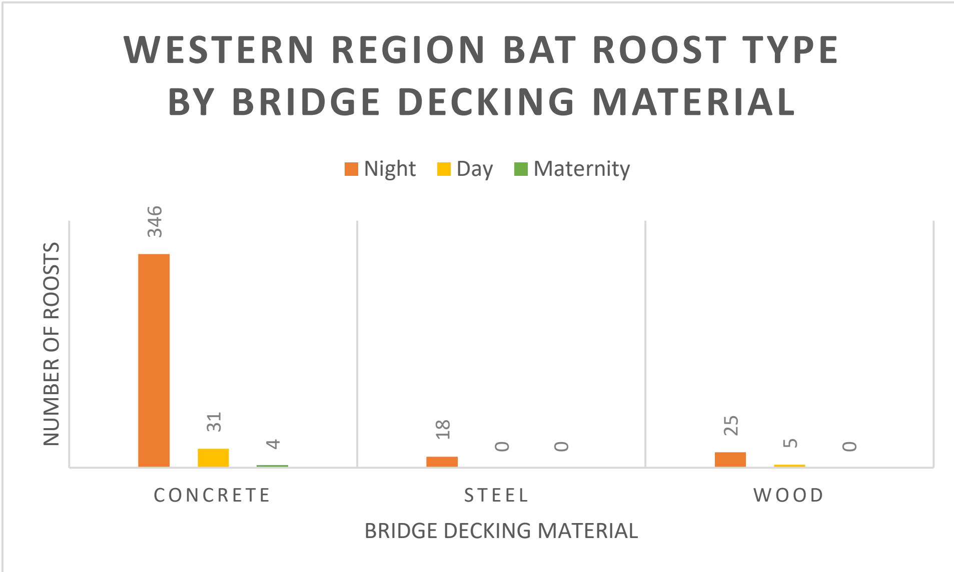

Figure 5: Total number of each type of bat roost present in each type of bridge decking material. Data from surveys in Western Montana. Bat roost type definitions are the same as for the other regions.

Comparing figure 1 and 5 shows some differences. In general, the spread of data for concrete and steel decking material look similar. However, for wood decking material, there are no maternity roosts found in the Western region. In the regions I surveyed, maternity roosts were only found in bridges with wood decking. In the western region, maternity roosts were only found in bridges with concrete decking material. Although the numbers are not very different (zero for wood bridges in the east and five for wood bridges in the west; four for concrete bridges in the west, and zero for concrete bridges in the east), these differences are still important to note. There are not many maternity roosts overall, therefore any difference in numbers could be significant.

The DNA results from the guano samples successfully identified six different species (Fig. 6). The graph below only shows those bridges which had successful DNA analysis results and does not include any samples which were unidentified due to poor DNA or other circumstances. Additionally, the number of bridges with each type of bat species is shown, instead of the number of samples of each bat species, since multiple samples were taken at the same bridge and could have come from the same bat.

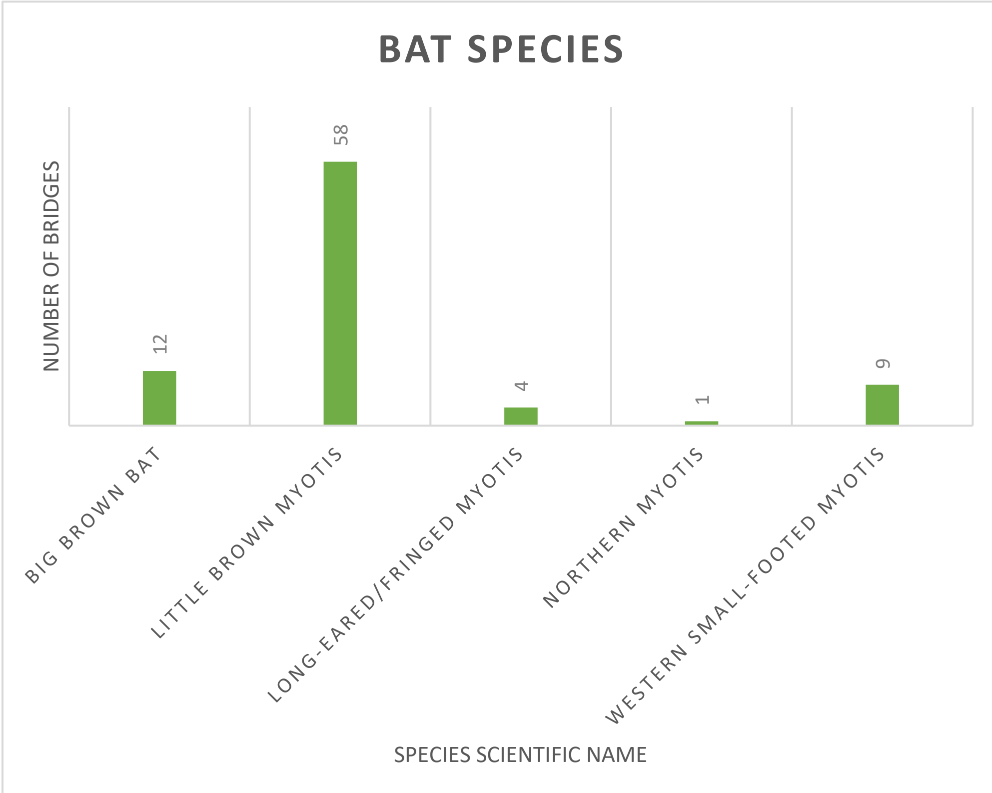

Figure 6: The number of bridges at which each type of bat species was found (species ID from DNA analysis from guano samples). Common names are shown and correspond to scientific names as follows: Big Brown Bat (*Eptescicus fuscus*), Little Brown Myotis (*Myotis lucifugus*), Long-eared Myotis *(Myotis Evotis)*, Fringed Myotis (M*yotis thysanodes)*, Northern Myotis (*Myotis septentrionalis)*, Western Small-footed Myotis *(Myotis ciliolabrum)*. The category with Long-eared/Fringed Myotis is due to the DNA testing method being unable to differentiate the two because of very similar DNA between these species.

Little Brown Myotis was the bat species found most often, showing up at 58 different bridges, while Northern Myotis was the bat species found the least often, at only one bridge. This indicates high use of bridges as roosting sites by Little Brown Myotis, and less common use by most of the other species. I also examined how decking material varied by bat species (Fig. 7.).

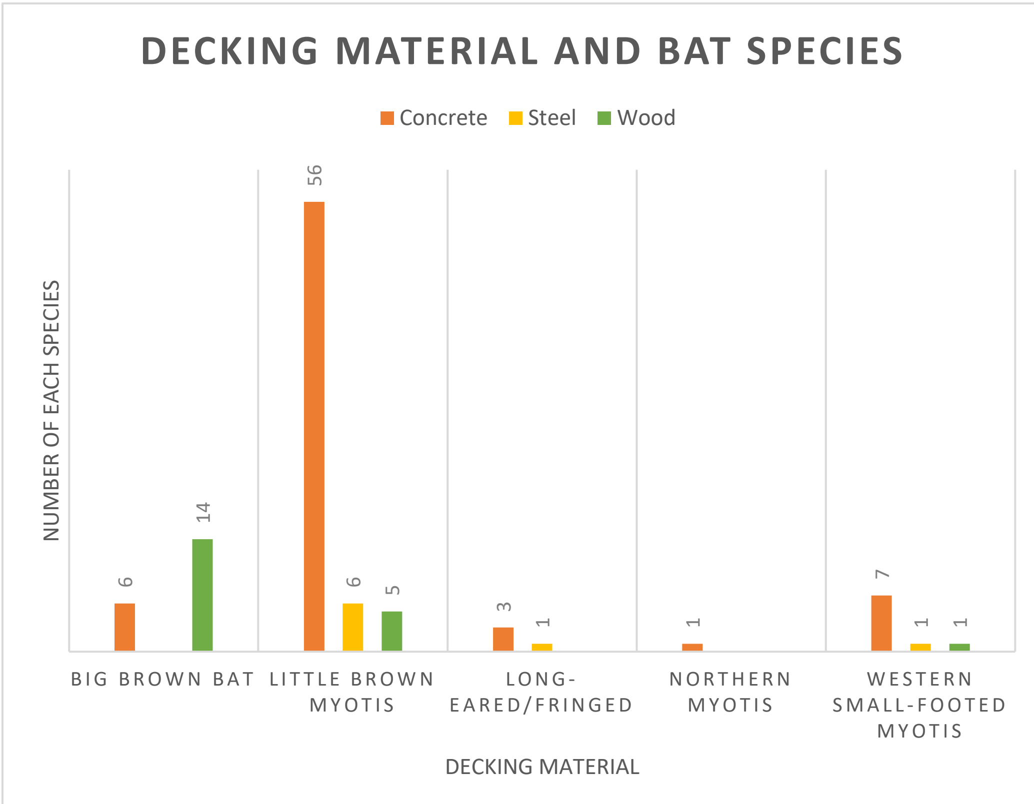

Figure 7: Decking material types used by each bat species identified by DNA analysis from guano samples taken at time of survey.

Most of the species identified used bridges with concrete decking more than bridges with the other types of decking, except Big Brown Bats, which used bridges with wood decking the most. Bridges with steel decking were used least. Next, I looked at the presence or absence of ideal crevices by bat species (Fig. 8).

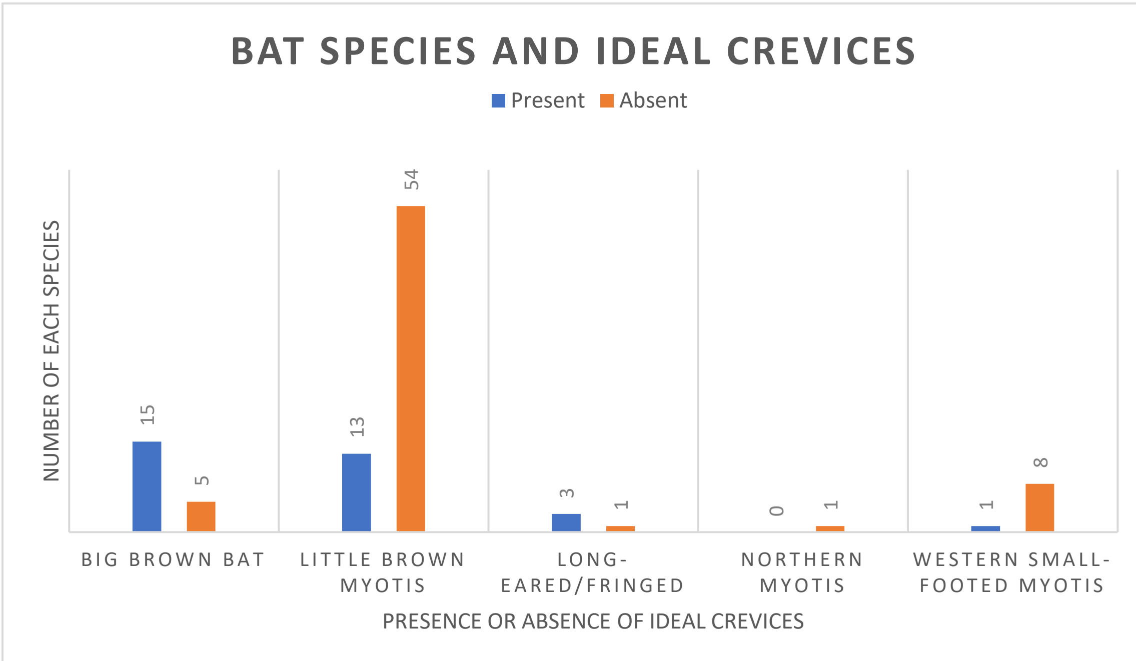

Figure 8: The presence or absence of ideal crevices in bridges, and roost selection by bat species (identified from DNA analysis of guano samples from bridges surveyed). Little Brown Myotis and Western Small-footed Myotis both were found more often in bridges without ideal crevices. Big Brown Bat was found most often in bridges with ideal crevices.

Discussion

The data I collected support earlier research indicating widespread use of bridges as roost sites by bats (Hendricks et al., 2005; Whittle, 2015). The percentage of bridges surveyed which had roosting bats is similar to past data (56%), further supporting the importance of bridges as roosting sites for bats. Additionally, my data show that night roosts were the most prevalent type (88%) of roosts (for bridges with bat use detected), whereas day and maternity roosts were less numerous, with maternity roosts being the least common. This is also in line with previous research that has been conducted in

Montana (Hendricks et al., 2005; Whittle, 2015). Concrete bridges were used the most but were also the most available roost type (they accounted for 54% of bridges surveyed). However, the data suggest that bat species could still be selecting for this type of decking material, as 78% of concrete bridges surveyed were used as some type of roost by bats, as opposed to 29% and 26% of available steel and wooden bridges, respectively. This could also be due to the fact that night roosts were the most numerous type of roost, and were most often found in concrete bridges, while day and maternity roosts were found more often in wooden bridges.

The data suggest that the presence of ideal crevices is essential for maternity roosts, important for day roosts, and not important for night roosts. These data further support the idea that ideal crevices are an essential feature in determining roost type (Whittle, 2015). Bridges equipped with ideal crevices could provide an essential roost feature for maternity-roosting bats. During the bridge surveys, I noticed that several bridges had ideal crevices that had been filled in with some type of insulation foam. If these crevices were not filled in, it would provide more potential day and maternity roosting structures for bats. Since most bridges surveyed did not have ideal crevices, this could be an explanation for why night roosts were the most numerous roost type.

When comparing my data with the data in Western Montana, I found an important difference. Bridges with wood decking were the only bridges in the regions I surveyed, that were found with maternity roosts. In Western Montana, only concrete bridges had maternity roosts. Therefore, my data contradicts what has been found by Whittle (2015). However, it is in line with what was found by Hendricks et al. (2005). The area of south-central Montana surveyed by Hendricks et al. is closer to the regions where I conducted my surveys, and more similar in landscape type. One reason for this difference in preference of concrete versus wood bridges could be that wood bridges are sometimes coated in creosote as a preservative, which could deter bat use (Adam & Hayes, 2014). This creosote-coating might occur in Western Montana more than in the central and Eastern regions, thereby altering roost preference across the state.

The results of the DNA analysis show that *E. fuscus* and several *Myotis* species use bridges as roosts, which is consistent with results from other surveys on bridge-roosting bats in Montana (Whittle, 2015, Hendricks et al., 2005). However, *M. septentrionalis*, or Northern Myotis, is a species known for tree roosting (Sasse & Pekins, 1996; Foster & Kurta, 1999), and has been less commonly found in man-made structures such as a barn (Cope & Humphrey, 1992) or bat roost boxes (Whitaker Jr. et al., 2006). This species has been scarcely documented in the state of Montana and has never before been documented to use a bridge as a roost site in this state (MTNHP point observation data). Given its status as threatened under the Endangered Species Act (April 2, 2015), this finding could be significant. Since bridges are man-made structures they could provide important roost habitat for Northern Myotis in place of the traditional tree roosts for this species, which are much less available in Eastern Montana. Additionally, the use of a bridge as a roost by Northern Myotis shows that bridge surveys in this study area are a valid method of surveying for this threatened species. Although the presence of Northern Myotis was only confirmed by DNA analysis at one bridge site, it is possible that it could be found at other sites, due to the methodology of guano sampling which was not comprehensive for each bridge, but rather, limited to one or two samples per bridge. Furthermore, bridge surveying is an efficient method of surveying as many bridges can be surveyed per day, and more area can be covered than other methods such as mist netting.

Bat species were found most often at concrete bridges, which corresponds to concrete bridges being the most available type. Big Brown Bats were the only species found more often in wooden bridges than concrete. Additionally, bat species were most often found in bridges without ideal crevices, except for Big Brown Bats which were found in bridges with ideal crevices most often. Perhaps the Big Brown Bat has different selection criteria for roost sites, however there are not enough data from this study to make firm conclusions. It is also worth mentioning that, due to the guano sampling methods, this study might not be representative of each species using bridges since there was a lot more guano available for sampling that was not collected and/or tested for species identification. Bridge surveys in the future could utilize more comprehensive guano sampling methods to provide a fuller picture of bridge use by roosting bats.

Literature Cited

Adam, M. D., & Hayes, J. P. (2014). Use of bridges as night roosts by bats in the Oregon coast range. *Journal of Mammology*, 81(2), 402-407.

Adams, R. A. (2003). *Bats of the Rocky Mountain West: natural history, ecology, and conservation*. Boulder, Colorado: University Press of Colorado, Boulder.

Agosta, S. J. (2002). Habitat use, diet and roost selection by the Big Brown Bat (*Eptesicus fuscus*) in North America: A case for conserving an abundant species. *Mammal Review*, 32(2),179-198.

Boyles, J. G., Cryan, P. M., McCracken, G. F., & Kunz, T. H. (2011). Economic importance of bats in agriculture. *Science Magazine*, 332(6025), 41-42.

Brooks, R. T., & Ford, M. W. (2005). Bat activity in a forest landscape of central Massachusetts. *Northeastern Naturalist*, 12(4), 447-462.

Brown, P. E., & Berry, R. D. (2005). *Bat surveys and the development of monitoring protocol for Santa Monica Mountains National Recreation area* (Report No. H8548020024).Thousand Oaks, CA: Brown-Berry Biological Consulting.

Cope, J. B., & Humphrey, S. R. (1972). Reproduction of the bats *Myotis keenii* and *Pipistrellus subflavus* in Indiana. *Bat Research News*, 13(9).

Fenton, M. B. (1997). Science and the conservation of bats. *Journal of Mammology*, 78(1), 1-14.

Foresman, K. R. (2012). *Mammals of Montana* (2nd ed.). Missoula, MT: Montana Press Publishing Company.

Foster, R. W., & Kurta, A. (1999). Roosting ecology of the northern bat (*Myotis septentrionalis*) and comparisons with the endangered Indiana bat (*Myotis sodalis*). *Journal of Mammology,* 80(2), 659-672.

Frank, C. L., Michalski, A., McDonough, A. A., Rahimian, M., Rudd, R. J., & Herzog, C. (2014). The resistance of a North American bat species to white-nose Syndrome (WNS). *PLOS one*, 9(12).

Harvey, H. T., Johnston. D., Tatarian, G., & Pierson, E. (2004). *California bat mitigation techniques, solutions, and effectiveness*. California Department of Transportation, project number 2394-01.

Hendricks, P., Lenard, S., Currier, C., & Johnson, J. (2005). *Bat use of highway bridges in south-central Montana.* Helena, MT: Montana Department of Transportation Research Programs.

Kunz, T. H., Arnett, E. B., Erickson, W. P, Hoar, A. R., Johnson, G. D., Larkin, R. P., Strickland, M. D., Thresher, R. W., & Tuttle, M. D. (2007). Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment*, 5(6), 315-324.

Kunz, T. H., Braun de Torrez, E., Bauer, D., Lobova, T., & Fleming, T.H. (2011). Ecosystem services provided by bats. *Annals of the New York Academy of Sciences*, 1223, 1-38.

Langwig,K. E., Hoyt, J. R., Parise, K. L., Frick, W. F., Foster, J. T., & Kilpatrick, M. A. (2016). Resistance in persisting bat populations after white nose syndrome invasion. *Philos Trans R Soc Lond B Biol Sci* 372 (1712).

McCracken, G. F. (1989). Cave conservation: Special problems of bats. *NSS Bulletin*, 51, 49-51.

Meteyer, C. U., Valent, M., Kashmer, J., Buckles, E. L., Lorch, J. M., Blehert, D. S., Lollar, A., Berndt, D., Wheeler, E., White, C. L., & Ballmann, A. E. (2011). Recovery of little brown bats (*Myotis lucifugus*) from natural infection with *Geomyces destructans*, white-nose syndrome. *Journal of Wildlife Diseases*, 47(3), 618-626.

Montana Natural Heritage Program. Animal Point Observation Database. 6 February 2018.

Sasse, B., & Pekins, P. J. (1996). Summer roosting ecology of northern long-eared bats (*Myotis septentrionalis*) in the White Mountain National Forest. P. 91-101 in Proceedings of the Bats and Forests Symposium of the British Columbia Ministry of Forests, Victoria, BC, Canada.

Turner, G. G., Reeder, D. M., & Coleman, T. H. (2011). A five-year assessment of mortality and geographic spread of white-nose syndrome in bats and a look to the future. *Bat Research News*, 52(2), 13-27.

Uecker, B., Pilgrim, K., & Schwartz, M. (2018). Project: DNA Species testing of bat guano and tissue samples submitted 2017 by the Montana Natural Heritage Program. Report by the United States Forest Service.

Whitaker, J. O., JR. (1995). Food of the big brown bat, *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. *The American Midland Naturalist*, 134(2), 346-360.

Whitaker, J. O., & Weeks, H. P. (2001). Food of *Eptesicus fuscus*, the big brown bat, in Indiana in the absence of cultivated fields and agricultural pests. *Proceedings of the Indiana Academy of Science,* 110, 123-125.

Whitaker, J. O. Jr., Sparks, D. W., & Brack, V. Jr. (2006). Use of artificial roost structures by bats at the Indianapolis International Airport. *Environmental Management*, 38(1), 28-36.

Whittle, E. (2015). *Bat use of bridges in Missoula, Ravalli, and Mineral counties in western Montana*. (senior thesis). University of Montana, Missoula, Montana.

Appendix A: Data sheets

Bridge Surveys for Bat Use

Bridge Information

Bridge ID:		Date:	Observer:	Road Type: 4-lane interstate 2-lane interstate 1-lane paved 2-lane unpaved 1-lane unpaved	Bridge Type: Culvert Decked
County:	Latitude-DD:	Longitude-DD:	Elevation (ft):	Feature Crossed: road flowing water standing water railroad other	Ideal Crevices? No Abutment Parallel Central Expansion
Percentage of Surrounding Habitat (top 4): Conifer forest_____ Deciduous Forest_____ Agriculture_____ Residential_____ Riparian_____ Grasslands_____ Wetland_____				Span Material: Concrete Steel Wood	Decking Material: Concrete Steel Wood
Start Time:	End Time:		Weather: Clear Overcast Partly Cloudy Rain Wind		
General Comments: Mark for return visit? Yes / No					

Roost Information

Roost #	Roost Type	Roost Feature	# Bats in Roost	Night Roost Classification	Species (Ex. 1x MYLU @17°C)
1	No Night Day Maternity	Crevice Depth <4" >4" Open Other ________		0 1 2 3 4	
2	No Night Day Maternity	Crevice Depth <4" >4" Open Other ________		0 1 2 3 4	
3	No Night Day Maternity	Crevice Depth <4" >4" Open Other ________		0 1 2 3 4	
4	No Night Day Maternity	Crevice Depth <4" >4" Open Other ________		0 1 2 3 4	
5	No Night Day Maternity	Crevice Depth <4" >4" Open Other ________		0 1 2 3 4	
6	No Night Day Maternity	Crevice Depth <4" >4" Open Other ________		0 1 2 3 4	
7	No Night Day Maternity	Crevice Depth <4" >4" Open Other ________		0 1 2 3 4	

Sketch of Photographed Roost Locations

* Side View
** Bottom View

* Include height of roost (side) and width (bottom) and photo locations. Label sides for orientation between views.
** Shade areas with droppings, circle (with number) locations of bat roosts.

# Active Nests	Cliff Swallow <5 5-10 10-20 >20	Barn Swallow <5 5-10 10-20 >20	Rock Pigeon: Yes / No

Other Notes (e.g. incidental species):