Bridging the Gap Between Bats & Transportation Projects

A Manual of Best Management Practices for Bridges, Artificial Roosts, & Other Mitigation Approaches for North American Bats

Prepared for

AASHTO Committee on Environment and Sustainability

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DISCLAIMER

BRIDGING THE GAP BETWEEN BATS AND TRANSPORTATION PROJECTS: A MANUAL OF BEST MANAGEMENT PRACTICES FOR BRIDGES, ARTIFICIAL ROOSTS, AND OTHER MITIGATION APPROACHES FOR NORTH AMERICAN BATS

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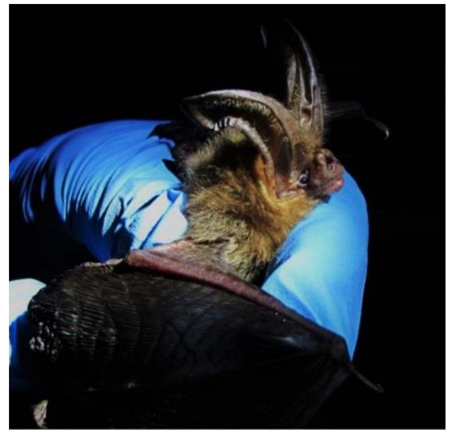
Interstate 81 crossing the New River. Photo credit ESI®

TABLE OF CONTENTS

1.0 INTRODUCTION

There is an increase in awareness about interactions between bats and transportation infrastructure. Bats, including several federal threatened and endangered species, occupy bridges throughout the contiguous 48 states. Bridges provide critical habitat and function as sites for maternity colonies, day roosts, and night roosts. This manual provides an overview of bat ecology to inform land managers, transportation biologists, and natural resource and wildlife agencies about general bat ecology and Best Management Practices (BMPs) for addressing potential conflicts between bats and transportation structures. BMPs are divided into three categories:



The federally endangered Virginia big-eared bat. Photo credit B. Meyer, ESI®

1) *Inspection* – recognizing habitat used or potentially used by bats,

2) *Avoidance and Minimization* – taking steps (i.e., avoidance and minimization measures) to reduce or eliminate negative impacts to bats, and

3) *Mitigation* – identifying options to off-set or mitigate negative effects of highway projects.

The National Cooperative Highway Research Program Project 25-25 Task 102 supported the research effort needed to create this BMP manual and a more technical companion document that includes pertinent statistical analyses and references. Most of this material is summarized herein with the goal of producing a concise and useful product for the end user.

The BMP manual is targeted toward professionals who regularly address interactions between transportation projects and environmental laws. Interviews conducted as part of the research effort revealed contrasting viewpoints between the professionals employed by transportation agencies (such as Departments of Transportation, DOTs) and those employed by resource-centric organizations including the U.S. Fish and Wildlife Service (USFWS), State Departments of Natural Resources (DNRs), and academics. Such divergent viewpoints arise from different goals (i.e., building projects as opposed to species recovery efforts) and from dissimilar areas of expertise. Expecting a transportation engineer to understand the details of bat biology is not reasonable and expecting bat biologists to understand the nuanced differences among different types of bridges and culverts is equally unreasonable.

Different perspectives naturally result from different objectives and can unnecessarily complicate communication. This manual contains sections dedicated to defining terminology to simplify communication, introducing the ecology of bats in the U.S., and describing methods to recognize when and why bats might be present in transportation structures. The format presents information such that it facilitates transportation professionals' understanding of how bat mitigation fits within the same framework used to address other issues related to environmental compliance.

Bridge crossing the Wabash River. Photo credit ESI®

2.0 DEFINITIONS/GLOSSARY

- Best Management Practices (BMPs): Activities that can be widely applied to obtain a desired result. In this document, BMPs enable safe construction and operation of transportation infrastructure that minimizes negative impacts to bats while maximizing potential benefits.

This bridge in North Carolina is used by at least two species of bats. Photo ESI®

- Bridge: Defined by the Federal Highway Administration (FHWA) as a structure including supports erected over a depression or an obstruction, such as water, a highway, or a railway; a track or passageway for carrying traffic or other moving loads; and an opening measured along the center of the roadway of more than 20 feet between copings of abutments (i.e., from end-to-end) or spring lines of arches (i.e., in diameter of arches), or extreme ends of openings for multiple boxes. A bridge may also include multiple pipes, culverts, or box culverts, where the clear distance between openings is less than half of the smaller contiguous opening.

Culvert in western Pennsylvania. Photo credit ESI®

- Culvert: Defined by FHWA as a structure designed to take advantage of submergence to increase hydraulic capacity. Culverts, as distinguished from bridges, are usually covered with material from the embankment and are composed of structural material around the entire perimeter, although some are supported on a spread footing where the streambed serves as the bottom of the culvert. Culverts, or series of culverts that extend along more than 20 feet of the roadway, are treated as bridges
- Echolocation: Natural sonar. Some animal species, especially bats, produce sounds that bounce off obstacles or targets in the environment. The returning echo is then interpreted by the animal to provide information about the obstacle or target.
- Enclosed Space: A term used herein to describe large open areas entirely confined within a larger structure such as those found within hollow trees, buildings, caves, culverts, and mines. Compare to protected open space below.

A biologist (blue shirt) searching a rocky outcrop in Virginia for roosting bats. Photo credit ESI®

- Karst: Landscapes underlain by water soluble rock formations such as limestone, dolomite, or gypsum. Recognizable features of such landscapes include caves, sinkholes (where the roofs of caves have collapsed), and streams that flow partly underground such that they appear and disappear from the surface. Many bat species rely on caves for habitat, especially in winter.
- High Wall: artificial cliffs created during mining.

- Limiting Factor: A resource whose limited availability limits the ability of bat populations to expand.
- Protected Open Space: A term used herein to identify spaces beneath bridges that are covered on the top and sides, but with an open bottom. A classic example is the space formed between support beams, pillars, and the road deck on an I-beam bridge.
- Roost: A place where bats stop when not flying. Multiple subcategories have been identified including:
  - Day Roost: Location where bats shelter during the day
  - Maternity Roost: Roost used by female bats and their dependent young. These are often viewed as the most important habitat element used by bats in summer and can be divided into several subcategories based on the time bats are present or the intensity of use.
    - Heavily used roosts are termed primary while rarely used roosts are alternate or secondary roosts.
    - Roosts may also be viewed as nodes in a communications web, with the most important roosts being those used by bats when moving between lesser-used nodes.
    - Bats sometimes move among several roosts during the maternity season such that separate roosts are used during pregnancy, parturition (giving birth), and lactation.
  - Swarming Roost: Roost used during the fall when bats gather in large numbers near caves and mines.
  - Transitory/Migration Roost: Roost used by bats moving between summer and winter habitats
  - Winter Roost(s)/Hibernaculum (pl. Hibernacula): Roost used when bats hibernate. The term 'hibernacula' is typically applied to enclosed spaces especially caves, mines, tree cavities, and buildings. Some bats also hibernate while hanging in trees or hiding in leaves on the ground.
  - Night Roost: Location where bats rest between foraging bouts.

This tree was used as a maternity roost by a colony of Indiana bats Photo credit ESI®

Biologists enter hibernacula to count hibernating bats, but unauthorized visits can harm the bats resulting in take. Photo credit S. Brodnick, ESI®

- Seasonal Avoidance: Completing work at a time when bats (or other wildlife of concern) are absent or rare within a habitat to avoid/minimize impacts to bats.
- Take: Under the Federal Endangered Species Act, take is defined as to harass, harm, pursue, hunt, shoot, wound, trap, capture, collect or attempt to engage in any such conduct. Similar definitions are used for many state laws aimed at the protection of natural resources. Conceptually, this concept extends the definition of a taking of private property (as would occur under a condemnation proceeding) to natural resources which are a public resource.
- White-Nose Syndrome (WNS): Fungal disease caused by the fungus *Pseudogymnoascus destructans*, which has killed millions of bats since it was introduced to the U.S. in the mid-2000s.

3.0 INTRODUCTION TO NORTH AMERICAN BATS

3.1 Diversity

The U.S. is home to four families and approximately 46 species of bats: Mormoopidae (ghost-faced bats, 1 species), Phyllostomidae (leaf-nose bats, 6 species), Molossidae (free-tailed bats, 8 species), and Vespertilionidae (common bats, 31 species). Most bats found north of Oklahoma are members of family Vespertilionidae. Bat diversity is highest in equatorial regions and decreases in northern latitudes.

3.2 Conservation Status

Several issues, prompting conservation concerns, are currently impacting bats. WNS has decimated several cave-hibernating species in the eastern U.S. and is now becoming established in the western U.S. Migratory species are being killed in large numbers by wind turbines. Species that both migrate and hibernate in caves are vulnerable to cumulative impacts from both WNS and wind turbines.

Declines in bat populations take many decades to recover. Endangered bat species, including the Indiana bat (*Myotis sodalis*), gray bat (*M. grisescens*), Virginia big-eared bat (*Corynorhinus townsendii virginianus)*, and Ozark big-eared bat (*C.t. ingens*) have a single pup every year. Other species such as the tri-colored bat (*Perimyotis subflavus*) have only two pups a year. Thus, minimizing take of these species is a very important consideration.

Many bats are protected by federal or state regulations that can substantially affect project time-lines – a key consideration for transportation professionals. The number of protected species could rapidly increase as WNS begins to impact western species.

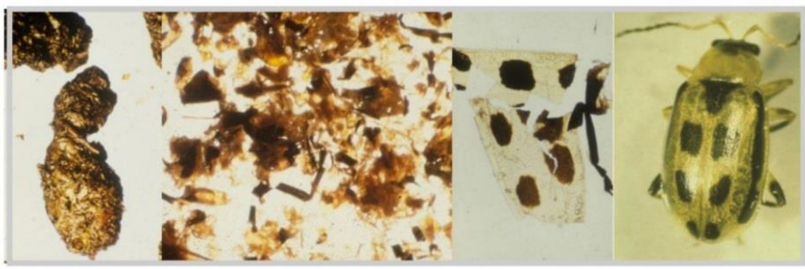
- Seven species are listed as federally endangered: Indiana bat; gray bat; Virginia big-eared bat; Ozark big-eared bat; Mexican long-nosed bat (*Leptonycteris nivalis*); Florida bonneted bat (*Eumops floridanus*); and the Hawaiian hoary bat (*Lasiurus semotus*).
- One species, the northern long-eared bat (*M. septentrionalis*), was listed as threatened in 2016 due to WNS.
- The tri-colored bat is currently under review for protection under the Endangered Species Act (ESA), and eastern populations of the little brown bat (*M. lucifugus*) are scheduled for review in 2023. Overall population numbers of both species are severely affected by WNS.
- Seventeen species of bats in the continental U.S. are considered species of concern by the USFWS.
- Multiple other species of bats are listed under state equivalents of ESA. Some states treat all resident bats as rare and protected.
- The lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*) was delisted in April 2018 due to effective regulations and conservation planning.

Left to Right: Northern long-eared bat; Gray bat; Indiana bat. Photo credits ESI®

3.3 What Bats Eat

Most bats in the U.S. are insectivorous. The non-insectivorous species occur along the U.S./Mexico border and include two vampire bats (that bite animals and lap the blood) and three species of long-nose bat that feed on pollen and nectar. Insectivorous bats have two main foraging strategies: *aerial hawking,* catching prey on the wing, and *gleaning,* capturing prey items from surfaces. Prey items vary among species but include many of the most important agricultural pests, such as the adult forms of the cotton boll worm, southern corn rootworm, Hessian fly, mosquitos, and other pest species. Some southwestern species, including pallid bats (*Anthrozous pallidus*) glean ground-dwelling arthropods including scorpions, centipedes, and beetles.

This little brown bat is using an aerial hawking strategy. Photo credit B. Dennis, ESI®



Insectivorous bats feed on a variety of insect prey. Dissection of a guano pellet from a big brown bat reveals pieces of insect that upon closer examination can be identified as the spotted cucumber beetle, which is also the adult form of the southern corn rootworm. Photo credits: Linda Castor (guano pellet) and John O. Whitaker, Jr. (whole insect).

3.4 Financial Impact of Bats

A paper by Boyles et al. (2011) quantified potential eco-nomic benefits of bats eating pest insects. The study noted that a single colony of 150 big brown bats in Indiana consumed approximately 1.3 million pest insects per year and that a single little brown bat consumes 4 to 8 grams of insects per night when active. When extrapolated across the landscape, foraging bats save farmers more than $3.7 billion in pesticide applications.

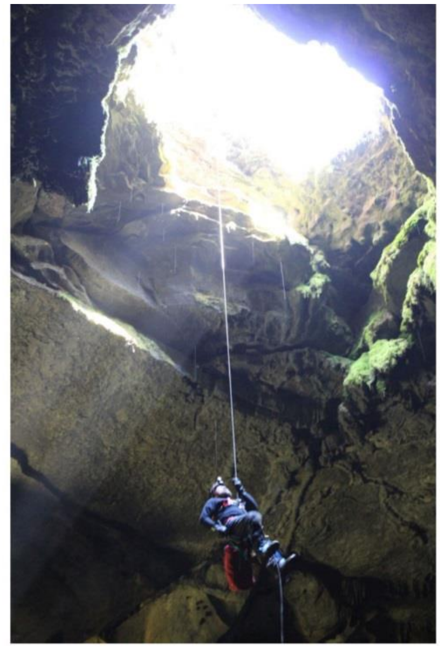
Three species of long-tongued bats serve as important plant pollinators for several crops, particularly agave used in the production of tequila in the desert Southwest and into Central America.

Tropical regions are home to many species of bats that eat fruit and spread seeds in feces. An approach to reestablishing tropical forests includes leaving isolated fruit trees in open areas to attract bats to the fruit and utilizing bats to spread seeds throughout the open area.

Farmers recognize potential economic benefits from bats whose diets include agricultural pests. Photo credit ESI®

3.5 Seasonal Ecology

Bats use a variety of strategies to deal with the changing seasons. Some, like the Brazilian free-tailed bat (*Tadarida brasiliensis* and the subspecies Mexican free-tailed bat, *T.b. mexicana*) and hoary bat (*Lasiurus cinereus*) make continental-scale migrations between summer and winter habitats. Others, such as the Indiana bat, make shorter, regional movements between forests in summer and caves in winter. Transportation professionals and bat biologists often take advantage of seasonal migratory movements and complete work when bats are rare or absent from a site. For example, repairing a bridge when resident bats are hibernating in a distant cave can preclude a project's potential negative effects.



Biologist entering a bat hibernaculum in Indiana. Photo credit D. Brack, ESI®

- Winter
  - Like birds, some bats simply migrate to warmer areas and do not hibernate.
  - Some bats such as red (Lasiurus borealis) and hoary bats migrate long distances, and hibernate in trees and other exposed habitats
  - Some bats make local or regional migrations to access underground hibernacula such as caves, mines, storm sewers, and culverts.
  - Several species exhibit very localized movements and hibernate in rock cracks.
  - Predictable temperatures are a key consideration for hibernating bats, thus any bridge that provides suitable habitat (type of space and temperature) may also be used by hibernating bats.

This northern long-eared bat carries a radio-tag that lets biologist follow it during migration. Photo credit B. Dennis ESI®

- Summer
  - Most North American bats live in trees during summer. Some species use enclosed places such as hollow trees, cracks in trees, and dead bark, while others live among the leaves. Bats that favor enclosed places occasionally also use buildings and bridges for habitat.
  - Only a few bats use caves year-round. When found under bridges, bats are typically using "enclosed open spaces" between the deck and the superstructure where a cave-like area is formed.
- Fall/Spring
  - Bats that hibernate in caves and mines often spend substantial time in an area near a cave both before and after hibernation.
- Migration
  - During migration bats use a wide variety of structures – several bridges are known as important migratory stop-over sites.

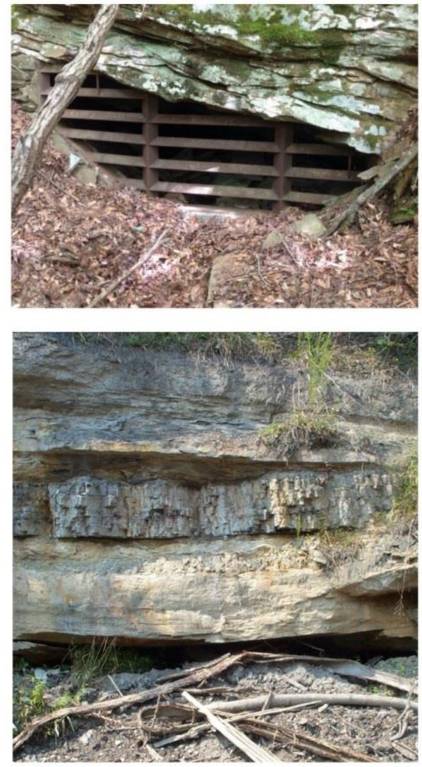
4.0 RECOGNIZING BAT HABITAT

Recognizing potential bat habitat is the first step toward reducing conflicts between transportation professionals and regulators entrusted with protecting bats. Presence of bats or their habitats potentially leads to a series of regulatory requirements. Bats make use of a wide array of habitats. They may roost in small cracks or crevices, in cavities, as well as in larger enclosed spaces.

4.1 Caves, Mines, and Other Underground Habitats

Only a few species of bats in the U.S. rely on caves as their primary habitat year-round and most of these species have undergone substantial declines resulting from cave disturbance. Most bat species rely on caves for staging, swarming, and winter hibernation, and many have successfully expanded their habitats to include mines and storm sewers. Underground habitat is often a limiting factor for bats and should be identified early by transportation professionals when developing a proposed project and then used to avoid impacts to bats. Detecting caves and mines requires the following steps:

- Check available resources for evidence of caves, mines, and other underground habitat – the most important sources of these data vary by region, but may include:
  - Topographic maps
  - USGS karst layers (within 50 feet of the surface)
  - Local chapters (called grottos) of the National Speleological Society
  - Underground mining databases
  - Groups interested in local history are often critical to identifying unique local attributes
- If evidence of underground voids is found – complete a search of the project workspace and surroundings to locate underground habitats
  - Examine aerial photographs – especially images taken when trees were without leaves
  - Pedestrian searches
  - In both cases, the searcher should understand landforms associated with openings as opposed to searching for openings



Top: Gated portal in Virginia.; Bottom: Mine portal in Kentucky, Photo credits ESI®

Top: Pedestrian search for portals in western Pennsylvania; Bottom: Recording portal information to determine suitability for bat use in Kentucky. Photo credits ESI®

- If underground habitats are found, then value to bats must be determined. Appropriate techniques vary by location and season and may include:
  - Assume presence and avoid
  - Examine entrance for signs that disqualify the site (too shallow, evidence of recent flooding)
  - Exit count at entrance
  - Entrance trapping by qualified personnel
  - Interior search by qualified personnel
  - If bats are found, work with resource agencies to avoid and address impact

A trained biologist prepares to enter a cave in Virginia. Photo credit ESI®

4.2 Forested Habitat

Most North American bats roost in trees during summer. Many bat species prefer roosting alone or in colonies within the cavities, crevices (very small cavities or cracks), or sloughing bark of large trees (in terms of both height and diameter). Several species roost alone among the leaves of trees. Some species of bats hibernate in trees. Small forested areas (including wooded fence rows) provide habitat for commuting or foraging bats.

Mist net set up across a forested stream in Arkansas. Photo credit ESI®

4.3 Buildings

Human structures, including culverts, bridges, sheds, wells, and other buildings, should be searched (by qualified personnel) for bats and bat sign.

A mist net full of little brown and Indiana bats that spend their days roosting behind the siding of this house. Photo credit ESI®

4.4 Rocky Habitat

Rocky habitats, such as talus slopes and rubble, are used by bats during both summer and winter. Many bats native to the western U.S. make extensive use of rocky habitat that ranges from living under rocks and boulders to living within cracks and crevices in high walls of mines and cliffs.

Rubble in western Virginia. Eastern small-footed bats are more likely to use rocky areas exposed to the sun. Photo credit ESI®

4.5 Bridges, Culverts, and Transportation Infrastructure

Transportation infrastructure provides bats with a wide variety of surrogates for naturally-occurring habitats. The following observations and their sources are also contained in the technical companion document.

- **Bridges:** bridges are the best-known example of bats using transportation infrastructure. Depending on structure, bridges provide habitat that mimics caves, rock and tree crevices, and even large, hollow trees.
    - More than half of North American species are documented as roosting in or under bridges.
    - Federally-protected species known to use bridges include the Indiana bat, gray bat, northern long-eared bat, and both federally listed subspecies of Townsend's big-eared bat (Virginia and Ozark big-eared bat).
    - A bat colony in Austin, Texas, is an important tourist destination and the home of nearly 1 million Brazilian free-tailed bats.
    - Suitable spaces, present within or under a bridge, are key features for identifying bat use. Suitable spaces often comprise vertical crevices between 0.5 and 1.5 inches (1.27 and 3.81 cm) wide that mimic cracks and crevices in rocks and trees. Some species may use of larger areas such as hollow portions (cavities) within bridges or the protected open space between supporting beams.
    - Bats prefer large bridges with concrete decks that cross streams in rural areas.

Roadway culverts in Ohio. Photo credits ESI®

- **Culverts:** cases of very long culverts functioning as artificial caves were noted. One recent study (Rosamond et al. 2018) noted that such culverts under multi-lane divided highways are important hibernacula in the Deep South.
- **Abandoned transportation tunnels:** bats in several states are known to use tunnels as hibernacula if the tunnels are protected from rapid temperature changes such that cold, stable conditions are maintained (like a natural cave).
- **Other Transportation Infrastructure:** any structure that mimics a habitat type used by bats has potential for use. Rock faces created when roadways are cut through hills are likely an under-recognized source of bat habitat. Bats also make use of infrastructure associated with bridges and culverts, including gaps in guard rails and gaps in masonry.

A colony of big brown bats roosting in the expansion crack of a bridge. Photo credit ESI®

New bridges can be erected with consideration for potential bat use, and existing bridges can be modified or retro-fitted to improve bat roosting suitability without sacrificing safety or operability. Both scenarios potentially provide artificial habitat for multiple bat species currently facing severe reductions in historical and natural habitat across the U.S.

Features and modifications include simple and straightforward efforts such as installing bat boxes on support structures and sides of bridge decks, or designing expansion joints, vent holes, or spaces between box girders wide enough for bat use.

4.6 Landscape Considerations

Many species of bats make extensive use of linear landscapes (woodland edges, streams, trails, and fence rows) during commuting and foraging. Protecting or enhancing these connections is an important component of project design considerations. In addition to providing linear landscape elements, streams and riparian areas provide bats with access to drinking sources – a key resource for animals with a protein-rich diet. Thus, providing bats with drinking water is a simple means of mitigation in areas such as the western U.S. and portions of Appalachia where such resources are limiting.

Mist-net setup. Photo credit ESI®

4.7 Survey Techniques

Bat biologists employ several different techniques to evaluate bat presence/absence on a landscape. Survey techniques are listed below.

4.7.1 Mist Nets

To capture free-flying bats, very fine nets are placed in corridors, such as fence rows or over streams, or water sources to capture bats. In the eastern U.S., corridors such as roads, Rights-of-Way (ROW), and streams used by bats to move between roosting and foraging areas are targeted. In the western U.S., where water is scarcer, drinking sources (including stock tanks and/or sewage lagoons) with potential to attract bats from many miles away are targeted and nets are placed over them. Surveys using this technique are completed by experienced bat biologists in possession of all necessary permits. Permitted biologists oversee each mist-netting site with multiple teams needed to complete large surveys. Benefits of this technique include bat identification (to species and reproductive condition) and the ability to radio-tag or otherwise mark individuals, where a transmitter is placed on a bat to track and locate the individual for a few weeks – thus providing additional data for more detailed studies.

Harp trap. Photo credit ESI®

4.7.2 Harp Traps

Harp traps are used when potential exists for capturing many bats in a short period of time and often used to trap bats at the entrances of caves and mines. The trap consists of two frames mounted back to back. On each frame, wires or fishing line runs from the top to the bottom, such that each frame resembles a musical harp. When bats approach the trap, they typically dodge the first group of strings, but collide with the second set and fall into a collecting bag at the bottom of the trap. Benefits include bat identification (to species and reproductive condition) and the ability to radio-tag or otherwise mark individuals for subsequent tracking.

Acoustic detector microphone. Photo credit D. Sparks, ESI®

4.7.3 Acoustic Bat Detectors

Modern bat detectors are self-contained and weather resistant devices and can be deployed for weeks (or even months) with only irregular maintenance. Bat detectors convert bat ultrasonic calls into a format (audio and/or visual) observable by people. Companies also produce software intended to identify the type of bat that produced the call. Bat detectors are an accepted survey technique for most rare species. Acoustic surveys often have a lower up-front cost because 1) the level of expertise required to place detectors is lower than that needed to obtain a permit to handle live bats, 2) a single trained biologist can deploy multiple detectors at a time, and 3) software can be used to quickly process resulting data.

However, the software programs cannot guarantee identification, and often a trained professional must visually examine calls. Often, acoustic surveys that identify threatened or endangered bat calls require subsequent mist netting for confirmation. Bat detectors only suggest presence and relative abundance of species on the landscape.

Biologists inspect a bridge in Indiana for signs of bats. Photo credit ESI®

4.7.4 Examining Potential Roosts

Structures, such as bridges, buildings, culverts, bat boxes, and (with training and permits) caves and mines, are entered and searched for bats or evidence of bats. Guano deposits on the ground or on the structure and/or staining are reliable indicators of bat use. Scattered pellets indicate intermittent use and large guano piles and significant staining indicate regular use. Some bats, especially the big-eared and pallid bats, bring prey to a night roost, thus pieces of insects, usually wings and legs, remain scattered about the roost. In protected sites, guano, staining, and culled insects may remain intact for years. During searches, other signs (odor, vocalizations, and presence of bat parasites) of bat occupancy are also noted.

Staining underneath bridge due to regular bat use. Photo credit ESI®

Incidental observations (visual or audible) during either the day or night warrant more in-depth studies by experienced bat biologists. DOTs in several states, including Minnesota, Indiana, and Arkansas, now include a simple check-off on state bridge inspection forms for signs of bat use. Follow-up studies determine whether bats are present and provide details about use.

Biologist inspects a bridge in Indiana from above for signs of bats. Photo credit ESI®

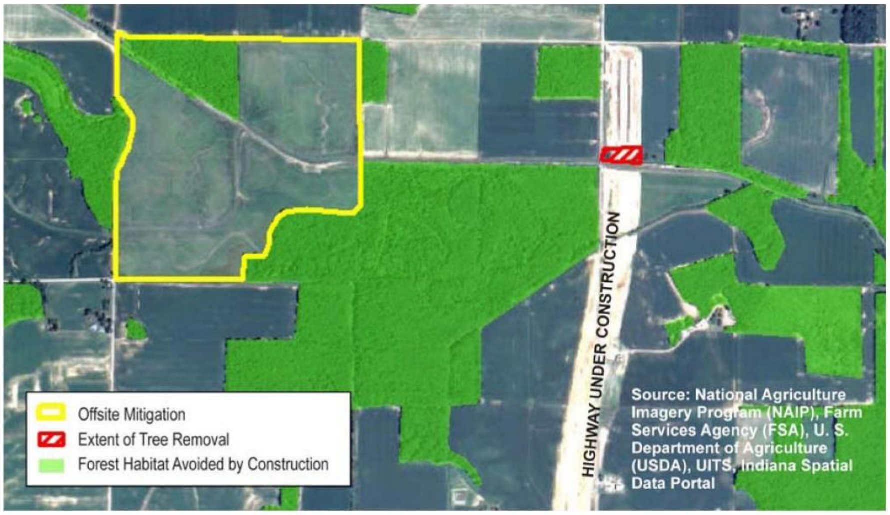
4.7.5 Emergence Counts

Emergence counts are used to determine roost locations and count the number of bats present within a structure. Thirty minutes before sundown, biologists position themselves close enough to a potential day roost to observe all facets of the structure, but not so close that natural activity is influenced or disrupted. Roosts are observed until one hour after sunset, or until darkness precludes accurate counting. The accuracy of emergence counts is greatly increased by supplementing the eyesight of the biologist with night vision, thermal cameras, and acoustic bat detectors. In some cases, USFWS allows removal of a roost or potential roost within 24 hours if no bats are seen exiting the structure. Emergence counts are appropriate for use on any structure where bats may roost.

Preparing for emergence counts at a potential roost tree. Photo credit ESI®

5.0 AVOIDING AND MINIMIZING IMPACTS

Through the Programmatic Biological Opinion (BO) for Transportation Projects in the Range of the Indiana and Northern Long-eared Bats, the FHWA, Federal Railroad Administration, and Federal Transit Authority entered an agreement with the USFWS to address impacts of highways on Indiana and northern long-eared bats (USFWS 2016). The BMP manual builds on guidance from many other environmental regulations and BMPs via a tiered approach where agencies avoid, minimize, and mitigate impacts from transportation projects. While the BMP manual provides information associated with the value of artificial roosts (especially bridges) as a way of mitigating impacts, the practitioner interviews revealed a need for better understanding of how such mitigation efforts fit within existing compliance processes.



A highway under construction. Designers avoided large blocks of forest (highlighted green) that provides habitat for bats; minimized impacts by crossing a stream that bats used to commute between forested blocks at a right angle, at location that limited tree removal (marked in red) to single row of small trees, and cut trees when bats were absent. Mitigation was provided on-site by using a bridge to serve as a wildlife underpass and by building new off-site wetlands and forests in the yellow area .

The first step in almost any effort to protect natural resources includes identifying ways to avoid and minimize project impacts (See map above). The most comprehensive way to incorporate bat conservation into transportation infrastructure design includes avoiding essential bat habitats (described earlier). Many habitats used by bats such as wetlands, riparian zones, caves, historic structures, and wood-lands are already avoided by transportation agencies. Early coordination with both state and federal natural resource and wildlife agencies provides a means of identifying known bat habitat.

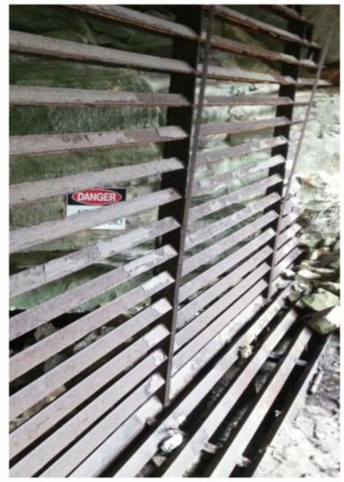
When projects cannot completely avoid known or suspected bat habitat, relegating impacts to time periods when bats are absent presents a viable alternative. As illustrated in the list below, the approach is commonly used for ESA consultations associated with Indiana, gray, and northern long-eared bats throughout their ranges.

- Impacts to summer habitat (clearing trees, removing bridges and buildings, and impacts to rocky habitat) are often completed after bats leave summer grounds for hibernacula. Dates vary by state, but in many locations the recommended window is between 1 October and 31 March. When summer impacts are unavoidable, it is often possible to avoid clearing during mid-summer when juvenile bats cannot fly (typically 1 June to 31 July).
- Work near known hibernacula is often restricted to midwinter, when all bats are below ground. This counterintuitive recommendation accounts for the fact that a few bats occur near the hibernacula throughout the active season (broadly 31 March to 1 November).

- Work affecting the interior of a hibernaculum is even more complicated (and very rare). Most work inside a hibernaculum is completed in mid-summer when resident bats can make use of alternate habitats. Input from a specialist is required prior to beginning work.

Often, suitable habitat is present, but bats are not. Unfortunately, this situation is likely to become far more common as WNS decimates remaining populations of cave-hibernating bats. Surveys provide data about areas that are occupied or unoccupied. These data are subsequently used to facilitate planning to avoid and minimize impacts to specific resources known to be used by bats.

6.0 MITIGATION TYPES FOR UNAVOIDABLE IMPACTS



Bat gate on known bat hibernacula. Photo credit P. Moore, ESI®

Understanding the biology of specific species is essential to successful mitigation. Based on available data, a successful mitigation effort must account for 1) the underlying physiology of the targeted bat species, which varies depending on seasonality, gender, and reproductive condition; 2) the behavior of targeted bat species, also varies depending on seasonality, gender, and reproductive condition; and 3) implementation of a monitoring program with a reasonable chance of determining/evaluating success. Additionally, development of a national database of roosting types, used to evaluate successes and failures without revealing the locations of specific projects or roosts is imperative.

Mitigation efforts are summarized by the type of activity, where it occurs relative to a project, and who completes the mitigation.

Habitat Preservation: A project proponent obtains credit for protecting existing habitat. Common examples of habitat preservation for bats involve protection of known hibernacula in exchange for impacts to summer habitat; preserving bridges known to harbor bats, or protection of known summer habitat at the expense of potential summer habitat. Habitat preservation yields immediate protection benefits because the habitat is already in existence, but net loss of habitat always occurs.


This free-standing bat box is being used to mitigate impacts from habitat removal. Photo credit ESI®

Habitat Enhancement: A project proponent takes steps to improve existing habitat including installation of bat boxes, timber-stand improvements, prescribed fire, control of invasive species, and installation of cave gates. Enhancement leads to an overall net benefit to the target resource by quickly converting areas of marginal quality into areas of high quality. If restored areas are still considered habitat, the overall effect remains a loss of habitat acres. To address this seeming inadequacy, proponents are encouraged to consider application of Habitat and Resource Equivalency Analyses (HEAs and REAs), allowing direct comparisons of restored habitat quality versus the quantity of habitat lost.

Habitat Creation/Restoration: New habitat is created, or degraded existing habitat is restored. Creation/restoration is most successful when either 1) the restoration is completed quickly, or 2) populations of target species are healthy enough to wait for new habitat to develop. The amount of habitat present is increased. Examples of habitat creation for bats include installation of artificial roosts in areas without roosting opportunities, use of bat-friendly bridge designs, planting forests to provide long-term bat habitat, efforts to create artificial caves, and removing exclusion mechanisms from historic hibernacula allowing bats access. Most bridges used by bats throughout the country are examples of unintentional habitat creation.

Combining Approaches: Previous sections describe habitat preservation, enhancement, and creation as discrete and diverse; however, the most successful conservation programs combine all three approaches. By simultaneously protecting a core area of high-quality habitat, restoring nearby degraded areas, and filling any needed gaps with created habitat, existing populations are protected and given room to grow. The oft-cited example of habitat mitigation for the Indiana bat at the Indianapolis Airport used a combination of approaches including purchase of existing woodlands (via noise abatement money), enhancement via installation of artificial roosts, and finally planting new forest around core areas. While not targeted at bats, wetland restoration efforts were completed adjacent existing bat habitat – subsequently providing bats with access to a high-quality foraging area. Recognition of the value of non-forested openings including wetlands, oldfields, parklands, and small agricultural fields to foraging bats led to protection and maintenance of some bat habitat areas.

This pond was created to provide drinking water for bats Photo credit S. Brodnick, ESI®

Bats in free-standing slat-style bat box with three chambers. Photo credit S. Brodnick, ESI®

6.1 Ways to Enhance Habitat

Efforts to enhance habitat consist of adding elements that are otherwise limiting. For bats, habitat is frequently enhanced by adding artificial roosts, although improving landscape connections and access to water are also important options for consideration. Descriptions of artificial roosts are provided below and illustrated in the table on the following page.

6.1.1 Stand-Alone Artificial Roosts

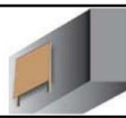
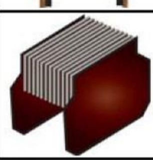
Efforts to install stand-alone artificial roosts began early in the 20th century (Storer 1926). In fact, the first purpose-built bat house was constructed by Dr. Charles A. R. Campbell near San Antonio near the beginning of the 20th century. Campbell's bat house was recently renovated based on its historic value. During intervening years, many artificial roosts were developed and range widely in size and cost. For classification purposes, artificial roost "styles" are sorted into the following categories: slat-style box structures, simulated sloughing bark, and protected open space. Contingent upon mitigation needs and project location, installation of one or multiple types of artificial roost structures provides a viable means of accomplishing mitigation goals.

Slat-Style Box Structures

Slat-style or birdhouse-style artificial roosts vary in size, construction material, and mounting. All designs comprise a series of slats that create small crevices called chambers for use by roosting bats. Slat-style roosts range in size from small, single-chambered structures, intended to accommodate a few bats, to very large structures such as bat condos, Missouri boxes, and Texas Bat Abodes that provide multiple chambers and potentially accommodate thousands of bats. Other styles, including rocket-style boxes, accommodate tens to hundreds of bats.

Boxes appropriate for specific applications are selected from the multitude of available designs. Small boxes are appropriate to satisfy creation of low-cost habitat for a relatively small number of bats. Installation requires a crew of two people and relatively simple tools. Conversely, larger boxes not only contain space for more bats, they also provide a wide range of temperatures. Larger boxes are more difficult to erect, and often require specialized equipment. Large structures are also more apparent on the landscape and susceptible to vandalism. Structures such as Texas Bat Abodes and Oregon Wedges are mounted directly to bridges, taking advantage of the thermal mass (tendency to heat and cool slowly) of the bridge itself and are visible only from a vantage point below the bridge.

Artificial roosts: Comparison of cost and performance.

Structure Type	Illustration	Cost to:				No. of Bats			
		Construct	Install	Maintain	Monitor	Spring	Summer	Fall	Winter
Slat-Style Boxes									
Single-Chambered Bat Box		$	$	$	$	🦇	🦇	🦇	-
3-Chambered Bat Box		$	$	$	$	🦇	🦇🦇🦇	🦇	-
Multi (>5)-Chambered Bat Box		$$	$	$	$	🦇	🦇🦇🦇🦇🦇	🦇🦇	-
Oregon Wedge		$	$$	$	$	🦇	🦇🦇🦇🦇🦇🦇🦇	🦇	-
Rocket Box		$	$	$	$	🦇🦇	🦇🦇🦇🦇🦇🦇🦇	🦇🦇	-
Missouri Box		$$$$$	$$$$	$	$	-	🦇	🦇🦇	-
Bat Condo		$$$$$	$$$$	$$	$	🦇🦇	🦇🦇🦇🦇🦇🦇🦇🦇🦇🦇	🦇🦇	-
Texas Bat-Abode		$$	$$$	$$	$	🦇🦇	🦇🦇🦇🦇🦇🦇🦇🦇🦇🦇	🦇🦇	-
Bark Imitations/Artificial Bark									
Wooden Shingles/ Shake		$	$	$	$	-	-	-	-
Shake Garland		$	$	$$	$$	-	🦇	🦇	-
Tarpaper Skirt		$	$	$	$	-	-	-	-
BrandenBark™		$$$$$$	$$$	$	$$	🦇🦇	🦇🦇🦇🦇🦇🦇🦇	🦇🦇	-
Bat Bark™		$$$	$$	$	$	🦇	🦇🦇🦇	🦇	-

$=Relative cost (greater number of symbols = greater cost); - = No bats

NOTE: Proprietary products included for completeness and not intended as an endorsement

Bark Imitations and Artificial Bark

Trees exhibiting sloughing bark are used by multiple tree-roosting bat species and existing trees can be modified to exhibit the same condition. Modifications include simple and inexpensive adaptations such as attaching a few un-treated wooden shingles (i.e., shakes) to the trunk in an overlapping manner. Installing more shakes to encircle the trunk (i.e., a shake garland), increases bat use potential. Tarpaper skirts are less expensive and comprise installing lengths of tarpaper (folded and wrapped) around a tree trunk, leaving a space beneath to allow bats to roost. Although inexpensive, these options likely support fewer bats than other artificial roosts and remain viable for only a short time. Very few bats used comparable structures at the Indianapolis Airport in the early 1990s.

To refine bark imitations, several efforts were undertaken to create longer lasting, artificial bark from materials such as nylon, fiberglass, and polyurethane (examples include the proprietary products BrandenBark™ and Bat Bark™). Initial studies suggest positive results regarding bat use of artificial bark and these products have gained acceptance from natural resource agencies. In side-by-side comparisons; however, modified artificial bark roosts proved less successful in attracting endangered Indiana bats than either rocket boxes (most used) or traditional slat-style boxes (moderately used). In this instance, evidence of preferred use of rocket boxes is linked to the structure's ability to provide appropriate temperatures throughout the summer. Notably, artificial bark roosts in the study were smaller than the commercially available size; a larger roost likely maintains greater thermal stability and provides a wider range of temperatures.

Protected Open Space

Protected open space is intended to simulate large cavities such as shallow caves or very large hollow trees, often used by bats for night roosting. On bridges, protected open space is created simply by leaving enough space between I-beams supporting the road deck. Where protected open space is not available (such as slab bridges) bridges can be retrofitted to provide such habitat. Texas Bat Abodes are occasionally built with fewer baffles to create small cavities for use by big-eared bats.

6.1.2 Bat-Friendly Bridges

In the Programmatic Biological Opinion for Transportation Projects (USFWS 2016), use of bridges or other artificial roosts as a mitigation tool is not mentioned. However, incorporating bat-friendly bridge designs into new construction or retrofitting less usable existing designs can provide substantial benefits.

This maternity colony of big brown bats was temporarily excluded from this bridge during recent repairs. A similar, bat friendly bridge built to carry increased traffic was used as mitigation. Note staining and guano on the bridge. Photo credit ESI®

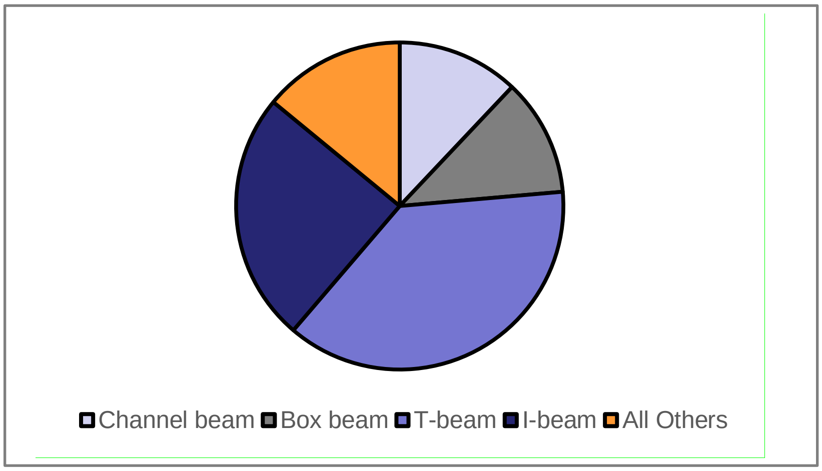
Bridges provide bats roosting opportunities that concurrently offer protection from both weather and predation during day and night roosting. Compared to bat boxes, bridges are also large structures and comprise relatively large thermal masses. Bridges are particularly valuable to bats in areas where natural roosting habitat is diminished, lost, or rendered unusable. Spaces and crevices between supports and beams, culverts and drains, and undersides of bridge decks provide roosting spaces, and the materials used to construct this infrastructure, specifically concrete, is coarse enough for bats to easily grasp while roosting. Several states indicated that bat-friendly bridge designs are implemented in efforts to attract colonies of bats.

Bats Prefer Bridges that Provide Roosting Space

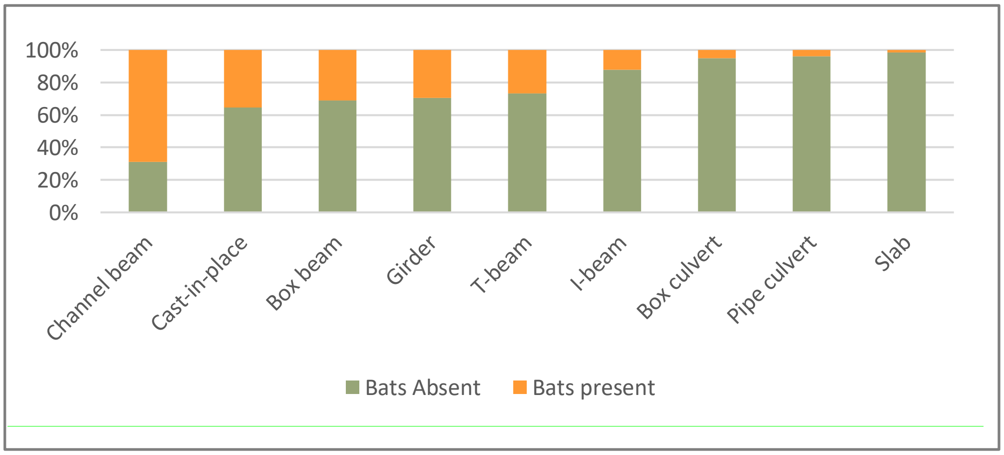
As detailed in the associated technical report, a review of nationwide data derived from literature and data provided by the Minnesota Department of Transportation identified some bridge components, materials, deck types, and features more likely to be positively correlated with bat presence than others (see pie chart below drawn from the literature review). Bridge types receiving substantial use include channel and box beam designs, providing bats ready access 0.5- to 1.5-inch (1.27- to 3.8-cm) wide spaces. In these designs, spaces extend along the underside of the bridge and allow bats to move within the crevice to select the best temperature. In addition to crevices occurring where roadway segments are joined, T-beam and I-beam bridges, and some girder bridges, provide protected open space where the deck meets the supporting superstructure. This open space is used by multiple species of bats at night and may provide day-roosts for big-eared bats. Cast-in-place bridges are used by large numbers of bats if the hollow interior of the structure is accessible or gaps occur between joints. Most other bridges provide few roosting opportunities for bats. Bats often take a few years to locate and use new artificial roosts (including bridges). It is also important to understand that as bridges age, they may develop structural defects (cracks and spaulds) or swallow nests that bats may use as a habitat (see bar chart below drawn from the literature review).

This bridge provides protected open space (between the I-beams), swallow nests, and any blocked downspouts, all suitable for use by roosting bats. Photo credit ESI®

Pie Chart Drawn from A Literature Review Showing 86% of Occupied Bridges Belong to Four Designs



Bar Chart Drawn from A Literature Review Showing Bridges Vary Widely in Occupancy Rates

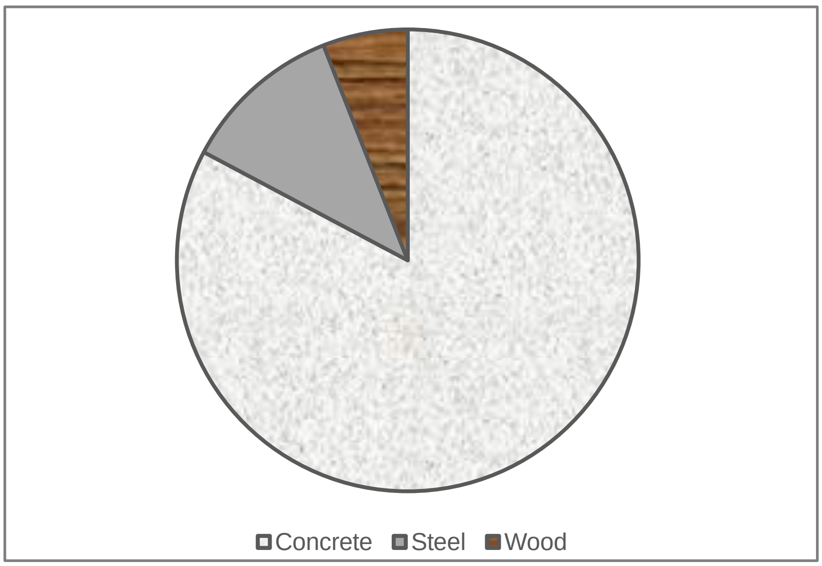


Size and Construction Material Matters

In a companion analysis using a large data-set provided by Minnesota DOT, factors potentially influencing bat use of bridges, beyond the presence of suitable roosting space, were examined. Comparison results revealed a preference for larger bridges and bridges built with concrete (especially the deck), which may reflect bat needs for stable and appropriate temperatures (see pie chart below). Temperatures above 113°F (45°C) are lethal to bats and wood and metal bridges with high solar exposure may exceed this limit. Concrete bridges have a higher thermal mass (i.e., are slower to heat and cool), allowing structures to stay below lethal temperatures during the day and retain heat at night —a particularly valuable factor when mother bats, in search of food, leave their pups at night.

Bats used several features on this bridge including space between the beams and this area of spaulding. Photo credit ESI®

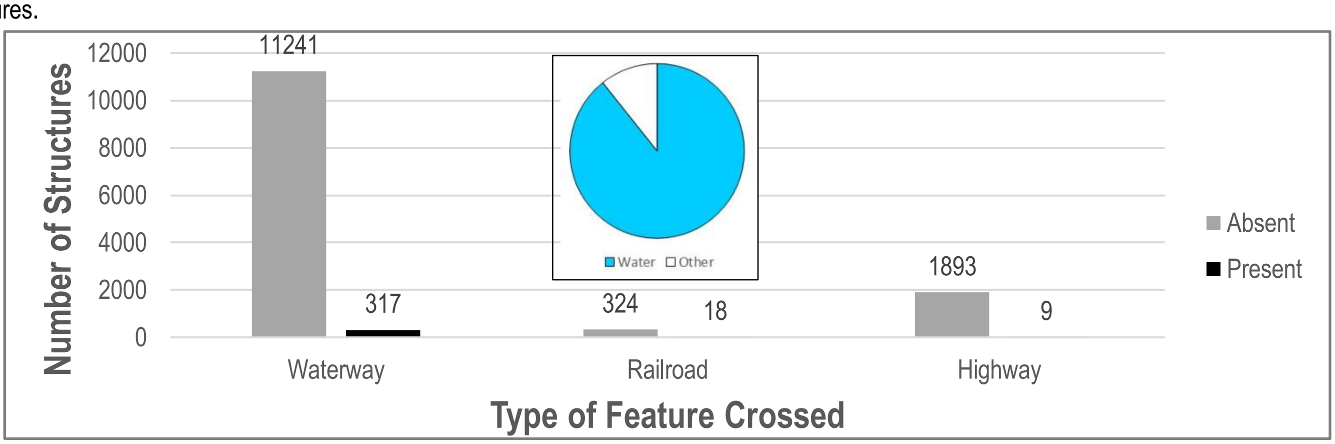
Pie Chart Drawn Based on Data Provided by Minnesota DOT Showing 83% of Occupied Bridges are Constructed of Concrete



Landscape Context Matters

Within this same analysis, a statistical preference for bridges across waterways was also noted (see charts below). Previous studies noted this pattern as well as a preference for bridges occurring in areas surrounded by natural and/or agricultural landscapes. Bridges are more frequently used by bats if they occur within or near areas already known as occupied (such as near hibernacula).

Bar and Pie Charts Based on Data Provided by Minnesota DOT Showing 89 % of Occupied Bridges Are Over Water. Some Bridges Cross Multiple Features.



Putting it all Together

Multiple bat species in North America roost in trees during summer and in caves during winter. In fall and spring bats concentrate roosting in trees and caves near hibernacula. Bridge features mimicking trees with cracks, crevices, hollows, and/or loose bark potentially provide day roosts in summer for many species including Indiana, California, Yuma, pallid, long-eared, big brown, small footed, long-legged, and little brown bats. The amount of solar exposure throughout the day (more solar exposure suggests higher likelihood of use) and height above ground comprise other factors important to determining day roost suitability. For night roosts, suitable height above the ground is important as well as proximity to potential foraging habitat is important to determining likelihood of use.

Species such as gray bats, Brazilian free-tailed bats, Townsend's, and Rafinesque's big-eared bats use caves year-round, and potentially would reside on a suitable bridge year-round. Eastern small-footed bats roost in cracks and crevices in stone features and use similar bridge features. Shelter, air flow, and temperature are important considerations to determine suitability as a year-round roost for cave-dwelling bat species, and species that use caves only for hibernation. Bridges used by migrating or swarming bats are most likely to be found near hibernacula.

What Bridges Are Candidates for Retrofitting

The best option for expeditiously increasing bat habitat includes retrofitting existing bridges with artificial roosts such as Texas Bat Abodes and Oregon Wedges. The information provided above indicates large bridges with concrete superstructures that cross waterways are likely suitable for installation of artificial roosts. Artificial roosts below the bridge deck should include vertical crevices as well as protected open space. By placing three-sided containers against the support pillars, a large hollow area is created that allows bats direct contact with the thermal mass (warmth) of the bridge, baffles could also be added to provide roosts for crevice-dwelling bats.

Biologist inspects a bridge for bats. Photo credit ESI®

Designing New Bridges

As referenced in the companion technical report, the following considerations are important when selecting a bat-friendly design:

- Provide protected open spaces, such as those created by an I-beam supporting a road deck. Protected open spaces simulate shallow caves or very large hollow trees and are often used by night-roosting bats.
- Provide small cracks and crevices measuring approximately 0.5 to 1.5 inches (1.27 to 3.81 cm) wide and several inches deep. Bats whose natural habitat includes rock crevices and protected spaces in trees, such as cavities, holes, cracks, and loose bark, are likely to use these spaces. In many cases, bats already use expansion joints and other cracks and crevices, currently a component of many existing bridges. Improve currently used locations by ensuring they are weather tight so bats do not get wet from water draining from the roadway.

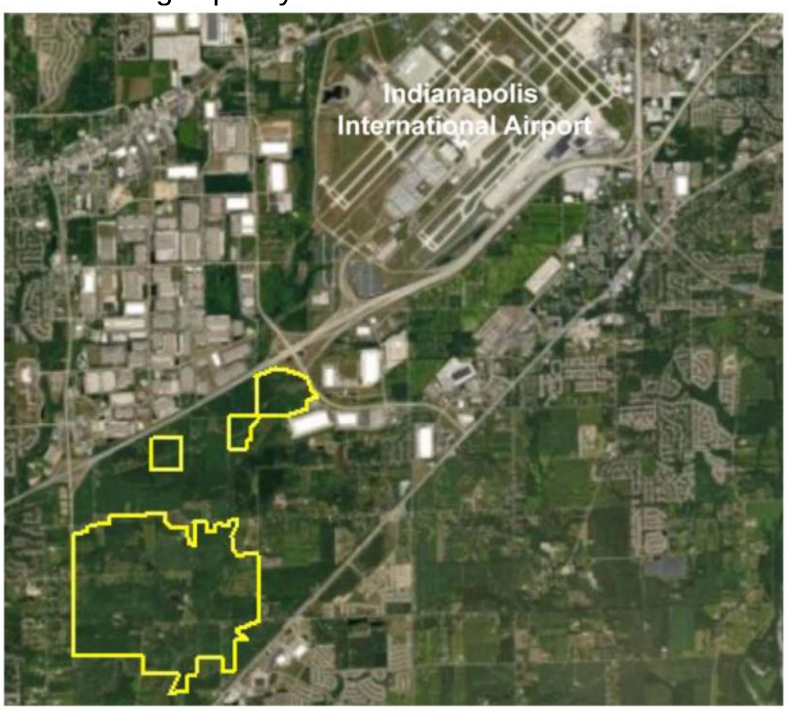
Data from 14 studies across North America suggest construction material is an important predictor of bat use. Thus consider the following when seeking to avoid or attract future bat colonies:

- Solid steel construction is an excellent predictor for bat absence, possibly attributable to heat retention characteristics.
- Bats regularly use bridges where a concrete road deck sits atop steel superstructures.
- Bats do not typically use bridges with flat-bottomed superstructures.
- Bats make regular use of concrete bridges that provide space for roosting.
- Wooden bridges are used in areas where concrete bridges are rare.

Bridge design with protected open space between beams that can be used by bats. Here, netting, foam sealant, and waterproof caulking were used to exclude roosting in the bridge joints during construction. Photo credit ESI®

6.2 Location of Mitigation (Relative to Impacts)

Mitigation is completed either on- or off-site relative to a project (See map below). On-site mitigation is often less expensive based on overlap with other project requirements and providing benefit to the affected population. By rapidly replacing habitat, on-site mitigation can be used to reduce impacts to a level considered temporary and discountable, which is not considered a take under the ESA. Off-site mitigation is often more expensive particularly when complex construction and monitoring are required. In such cases, an economy of scale is attainable by bundling mitigation from multiple projects, a common practice for Habitat Conservation Plans (HCPs). Combining mitigation from several sources is highly beneficial to target species when mitigation from multiple similar projects are pooled into large blocks of high-quality habitat.



The Indianapolis International Airport has successfully mitigated the impacts of several projects on Indiana bats since the 1990s. The areas highlighted in yellow are considered on-site mitigation because most of these lands were acquired for noise abatement purposes as part of a runway expansion. By restoring some habitats in advance of expected future impact the Airport also became a de facto mitigation bank. The mitigation program included preservation of existing woodlands, placing artificial roosts in woodlands to enhance their value, and planting of new forest to create new habitat.

6.3 Common Financial Approaches to Mitigation

Transportation agencies sometimes own properties potentially useful for mitigation. An under-valued source of such lands occurs when transportation agencies facilitate a willing sale by acquiring more property than needed for a project. For example, the backbone of successful mitigation efforts for bats and wetlands at the Indianapolis Airport was formed by lands acquired for noise abatement purposes (See map above). Residual properties likely provide low-cost mitigation options. In some cases, transportation agencies simply purchase land from third parties for the express purpose of mitigation (i.e., fee-simple mitigation). *In lieu* fee systems require that project proponents pay into a fund and fees are subsequently used by natural resource and wildlife agencies or third-party contractors to purchase and manage high priority conservation areas. *In lieu* systems remain viable options provided the sites preferred for acquisition are not desirable for commercial uses and/or are relatively abundant. If habitat targeted for acquisition is rare enough and demand high enough (such as lands within five miles of a cave) market forces may lead to substantial increases in the costs per acre of habitat acquired with the fees. Long term, many *in-lieu* fee systems fail due to a scarcity of suitable properties, changes in commercial uses of those properties, and a desire of conservationists to purchase only exceptional sites. Finally, mitigation banks involve a third party who protects or creates habitat and sells credits to project proponents. A key benefit of mitigation banking typically includes a transfer of liability to the conservation bank as part of the purchase agreement. The bank is also tasked with long-term monitoring and maintenance. Mitigation banks benefit targeted resources when they are designed by knowledgeable biologists and multiple small impacts are consolidated into large areas of quality habitat. Regardless of the approach, many mitigation lands are eventually transferred to a conservation organization for long-term management.

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8.0 ADDITIONAL READING AND RESOURCES

The resources listed below represent a selection of the resources reviewed as part of this project. For an complete bibliography, access the technical report at:
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