Acceptable Management Practices for Bat Species Inhabiting Transportation Infrastructure

April 2018

Please cite this document as: White-nose Syndrome Conservation and Recovery Working Group, 2018. Acceptable Management Practices for Bat Species Inhabiting Transportation Infrastructure. A product of the White-nose Syndrome National Plan (www.whitenosesyndrome.org). 49 pp.

Document adapted from Smith, H. J., and J. S. Stevenson. 2013. Linking conservation and transportation: a 'bats in bridges' report. New Mexico Department of Transportation Task No. 5372-33. <http://issuu.com/rdwildlifemanagement/docs/rdwm_nmdot_magazine_39e2c4474c50a4/0.>

Images by Justin Stevenson, RD Wildlife Management unless otherwise noted

This document is a product of the multiagency White-nose Syndrome Conservation and Recovery Working Group, established by the White-nose Syndrome National Response Plan (A National Plan for Assisting States, Federal Agencies, and Tribes in Managing White-Nose Syndrome in Bats). Specifically, the White-nose Syndrome Conservation and Recovery Working Group identified the need for acceptable management practices to minimize negative impacts to local bat communities during operational activities at transportation infrastructure (e.g., bridges, culverts).

Although applicable to every bat species, these measures were developed specifically to protect those whose populations have declined significantly due to white-nose syndrome. As such, this document addresses concerns relative to bat occupancy, and outlines methods to minimize colony disturbance and the further expansion of this disease. Background information on the significance of, threats to, and biology and behavior of bats illustrate the context and justification for these standards.

For more information on WNS please visit http://whitenosesyndrome.org.

1.Introduction

Globally, bats are intrinsic to healthy ecosystems, community integrity and vital ecological processes. They provide valuable ecosystem services (e.g., insect suppression, pollination, seed dispersal), products and provisions (e.g., tequila, durian, sisal, cactus fruits), cultural benefits (e.g., educational, recreational, spiritual) and contribute considerably to mammalian diversity. Notwithstanding, bats confront multiple threats. Habitat destruction and modification, climate change, pesticides and pollution, disease and human development (e.g., wind turbine facilities, urbanization) cumulatively contribute to population level impacts. Additionally, roost availability and abundance are critical elements limiting chiropteran populations. As the availability and abundance of natural roosts decline, manmade infrastructure (e.g., mines, buildings, bridges, culverts) become incalculable substitutes. Highway structures function as comparatively permanent, alternative roosts (e.g., diurnal roosts, nocturnal roosts, maternity roosts) and stepping-stone refugia (i.e., transitory roosts) for migratory populations. These anthropogenic structures proffer physical and thermal characteristics reminiscent of natural cavities (e.g., stable microclimatic conditions, predator protection) and proximity to elemental resources (i.e., water, optimal foraging sites).

State Departments of Transportation (DOTs) are increasingly incorporating environmental compliance, sustainability and stewardship within transportation planning, project development, construction, maintenance and operations. Furthermore, the exigency for environmental stewardship practices, procedures and policies echoes public concern for environmental integrity, habitat connectivity and biological conservation. Today, transportation authorities' mission espouses the larger societal objective of environmental excellence and sustainable transportation (American Society of State Highway and Transportation Officials 2016). As such, consideration to wildlife movements (e.g., mammal collision mitigation measures), ecosystem impacts (e.g., establishment of replacement wetlands and habitat enhancement) and phenological timetables (e.g., stream crossings and fish spawning, bird incubation periods) are increasingly at the forefront of transportation planning. Moreover, numerous states have become environmental champions, actively engineering and retrofitting highway structures to accommodate bat colonies (http://environment.transportation.org).

Forty-seven microchiropteran species of 20 genera and three families populate the United States (Loeb et al. 2015). Of those species, 61.7 percent (29) and potentially 87.2 percent (41) exploit manmade transportation infrastructure (See Table 1); however, 100% may be vulnerable to activities that encompass a larger footprint. North America's transportation system encompasses ca. 13 million structures (i.e., > 6 m bridges, box culverts, drainage structures) that equate to approximately one construction per quarter mile (400 m). With potentially millions of linear "bat-friendly" footage, DOTs inadvertently provide thousands of artificial roosts per state, supporting an inestimable number of bats. Given the magnitude of present-day threats (e.g., white-nose syndrome, turbine collisions) and concomitant population declines, it has become increasingly important to minimize ancillary sources of mortality.

Operational activities that adversely affect bats primarily include roost destruction, modification of habitats and direct disturbance during critical life phases (i.e., maternity and weaning periods, hibernation). Even those projects with uncomplicated scopes (e.g., pavement rehabilitation and reconstruction, bridge deck replacement, guardrail and fencing installation, timber treatment) and minimal environmental impacts may cause disturbance to resident colonies (Bat Conservation Trust 2007, Hinde 2008).

The interdisciplinary relationship between transportation ecology and bat ecology is an emerging and continually evolving field of study. Definitively identifying and addressing potential interactions necessitates a landscape-level, holistic strategy that contemplates the 'zone of influence' (ZoI, the areas/resources that may be affected by the biophysical changes caused by activities associated with a project; Bat Conservation Trust 2007). This document addresses one elemental component of the ZoI—individuals at the 'epicenter of impact.' Through structure-focused AMPs, we endeavor to provide informative, achievable guiding principles and concepts to identify bat presence/absence and thereby minimize potential impacts.

> Please become familiar with your state's endemic bat species and their respective maternity seasons, which vary by species and region. Contact your state wildlife agency to identify specific details about time-of-year restrictions, regulations, sensitive species (i.e., T&E species, state species of concern) statutes and/or requisite permits. Please note, the standards within this document may not be sufficient to eliminate, minimize, or mitigate impacts to bat species.

2. Structure Specific Misconceptions

The publication 'Bats in American Bridges' (Keeley and Tuttle 1999) remains the authoritative work for bats and transportation structures. Although this document provides an incredible wealth of information, people inaccurately consider their "ideal" characteristics as categorical requirements. This can precipitate misconceptions and erroneously influence surveyors or consultants and therefore, cause oversights with respect to bat occupancy. Bats exhibit considerable plasticity, both within and between species. Therefore, implementing a "one size fits all" approach to 29, and potentially 41, different bat species may effect devastating consequences.

"While there are clear similarities among the different bat species, it is important not to generalize about them. What is possible for one bat species is impossible for another. In taking protective measures and undertaking construction planning it is generally advisable to take into account the most discriminating bat species" (Limpens et al. 2005).

Misconception 1 | Bats require at least 3 m of vertical measurement to take flight. Therefore, the structure must be equal to or exceed 3 m to be suitable for bats.

Although structures < 3 m may not be preferable, to dismiss these roosts would be imprudent and irresponsible. Bats commonly occupy the warmest 'end chambers' – terminal spans that typically occur over land, proximate to abutments. Sloping riverbanks and/or the application of fill to stabilize bridge supports often cause end chambers to be closer to the ground than center chambers, and occupied chambers occasionally are < 2 m above ground. Suitable roosts within crevices and drainage pipes may be 2.28 m, with pipe entrances 1.20 – 2.59 m above ground (Smith and Stevenson 2013b). Furthermore, high occupancy rates may force bats to roost at substandard heights (e.g., .45 m from ground to roost entrance; personal communication, September 10, 2011).

Misconception 2 | Culverts are unsuitable due to the absence of crevices or perching substrate.

Boulay and Noggins (1999) state that, "we excluded culverts because we considered them unsuitable for roosting due to a lack of crevices or perching substrate." However, culverts indisputably provide habitat for diurnal roosting species (*Corynorhinus rafinesquii*, Lance et al. 2001, Bennett et al. 2008;

Table 1. American bat species and their likelihood of occupancy with respect to transportation structures (i.e., bridges, culverts); summarized from Phillips and Jones 1971, Keeley and Tuttle 1999, MacGregor and Kiser 1999, Kunz and Reynolds 2003 and Hendricks et al. 2004.

Species	Chance of occupancy	Susceptible to WNS
Antrozous pallidus, pallid bat	yes	
Artibeus jamaicensis, Jamaican fruit-eating bat	yes	
Choeronycteris mexicana, Mexican long-tongued bat	yes	
Corynorhinus rafinesquii, Rafinesque's big-eared bat	yes	
Corynorhinus townsendii, Townsend's big-eared bat	yes	
Eptesicus fuscus, big brown bat	yes	yes
Euderma maculatum, spotted bat	probable	
Eumops floridanus, Florida bonneted bat	proba	
Eumops underwoodii, Underwood's bonneted bat	probable	
Idionycteris phyllotis, Allen's big-eared bat	probable	
Lasionycteris noctivagans, silver-haired bat	yes	
Lasiurus blossevilli, western red bat		
Lasiurus borealis, eastern red bat		
Lasiurus cinereus, hoary bat	yes	
Lasiurus ega, southern yellow bat		
Lasiurus intermedius, northern yellow bat		
Lasiurus seminolus, seminole bat		
Lasiurus xanthinus, western yellow bat		
Leptonycteris nivalis, Mexican long-nosed bat	probable	
Leptonycteris yerbabuenae, lesser long-nosed bat	yes	
Macrotus californicus, California leaf-nosed bat	yes	
Molossus molossus, Pallas' mastiff bat	probable	
Mormoops megalophylla, Peter's ghost-faced bat	probable	
Myotis auriculus, southwestern myotis	probable	
Myotis austroriparius, southeastern myotis	yes	
Myotis californicus, California myotis	yes	
Myotis ciliolabrum, western small-footed myotis	yes	
Myotis evotis, long-eared myotis	yes	
Myotis grisescens, gray myotis	yes	yes
Myotis keenii, Keen's myotis	proba	
Myotis lucifugus, little brown myotis	yes	yes
Myotis melanorhinus, dark-nosed small-footed myotis	probable	
Myotis occultus, Arizona myotis	yes	
Myotis septentrionalis, northern myotis	yes	yes
Myotis sodalis, Indiana myotis	yes	yes
Myotis thysanodes, fringed myotis	yes	
Myotis velifer, cave myotis	yes	
Myotis volans, long-legged myotis	yes	
Myotis yumanensis, Yuma myotis	yes	
Nycticeius humeralis, evening bat	yes	
Nyctinomops femorosaccus, pocketed free-tailed bat	probable	
Nyctinomops macrotis, big free-tailed bat	yes	
Parastrellus hesperus; canyon bat, western pipistrelle	yes	
Perimyotis subflavus, tri-colored bat	yes	yes
Tadarida brasiliensis, Mexican free-tailed bat	yes	

Myotis austroriparius, *M. grisescens*, *M. leibii*, *M. septentrionalis* and *M. sodalis*, Ellison et al. 2003; *Perimyotis subflavus*, Sandel et al. 2001). An opportunistic examination of culverts within Socorro County, New Mexico suggests high occupancy rates (71.4-100%), comparable to similar preliminary studies, which document occupancy rates of 53.3% to 85% (Smith and Stevenson 2016; Walker et al. 1996, Boonman 2011). *Corynorhinus townsendii*, a State of New Mexico Species of Greatest Conservation Need (SGCN) was commonly present, exhibiting occupancy rates of 77.7%. Multiple species, including *C. townsendii*, were present October-January and across the United States, several publications document culvert use November - March (Benson 1947; Cel'uch and Ševčík 2008; Martin et al. 2005, 2011; Sandel et al. 2001; Smith and Stevenson 2013a, 2016; Walker et al. 1996).

Misconception 3 | Culverts must be between 1.5 and 3 meters in height and ≥ 100 m in length.

Documentations of suitable culverts include lengths of 10 – 19 m, widths of 1.0 – 1.5 m and heights of 1 – 4 m above ground or water. An evaluation of 44 culverts by Boonman (2011) determines lowest height and cross-sectional area amenable to bats are 0.4 m and 1.2 m^2, respectively. An opportunistic examination of four culverts by Bender et al. (2010) reports occupied culverts less than one-third the length of previously documented culvert roosts. They conclude that "researchers conducting structure surveys based on previously published data would overlook these smaller culverts or characterize them as unsuitable roosting habitat based on their less than 'ideal' characteristics." A preliminary survey of 15 box culverts along Interstate Highway 45, southeast Texas documents *Myotis austroriparius*, *Perimyotis subflavus* and *Eptesicus fuscus* (Walker et al. 1996). Culverts vary from 60-120 m length, 1.2 – 2.2 m height and 1.2-1.8 m width, commonly with standing water and entranceway vegetation. The IUCN near threatened species, *Choeronycteris mexicana*, has been found roosting within 45 – 61 cm wide corrugated metal culverts (Keeley and Tuttle 1999). In New Mexico, Smith and Stevenson (2016) document minimum culvert heights of 0.6 m and .93 m for *Myotis* and *Corynorhinus townsendii*, respectively.

Misconception 4 | Bats exhibit obvious signs of occupancy (e.g., bat vocalizations, guano and/or urine stains).

Bats commonly roost between narrow spaces above bridge beams, above or behind intact expansion or insulation boards, within concrete spalls, pipe collars and similar crevices whose openings are not oriented towards the ground, where guano accumulation is evident.
Bats possess a complex, diverse repertoire of social vocalizations. However, roosting bats may display minimal movements and vocalizations.

Misconception 5 | Bats require vertical crevices 12.7 to 31.75 mm wide and ≥ 304.8 mm in depth.

Bats exhibit incredible plasticity with respect to amenable roost types and will exploit uncommon structures including concrete spalls; space above insulation boards; between guardrail posts and beams; between concrete piers and corrugated metal; within insulated pipes, swallow nests, wasps' nests, drainage pipes, recessed lighting housings and road signage.

Misconception 6 | Bats only roost within bridges over water.

For most species, a dramatic correlation exists between colony location and distance to water; riparian areas are often highly profitable foraging territories for insectivorous bats. Proximity to water may constitute minimum habitat characteristics for some species; however, flight enables bats to access widely distributed resources. For example, *Tadarida brasiliensis* may travel 40-50 km between day roost and foraging habitat. While proximity to water certainly increases habitat suitability, its presence or lack thereof does not determine occupancy.

Misconception 7 | DOTs can safely conduct operations after October 1, when bats are absent. This interval coincides with autumnal migration and movements to local hibernacula.

In temperate North America, colder months signify lower ambient temperatures and the concomitant reduction of insect prey. To circumvent this ‘energetic bottleneck’, migratory species relocate to warmer environments, whereas other species hibernate and remain relatively inactive. Some species exhibit intraspecific plasticity relative to winter activity patterns, which vary from sustained hibernation to intermittent dormancy. In the southern United States, many non-migratory species are active year-round, even at low ambient temperatures (-8 – 22 C). The potential for overwintering or hibernating bats necessitates a survey to determine presence between October – March.

Misconception 8 | Roosts must receive full sun exposure.

A recent study (Smith and Stevenson 2013b) supports the contention that small heterothermic (i.e., employ daily torpor) bats occupy relatively wide temperature ranges, and are opportunistic relative to roost structures and conditions. Additionally, their results illustrate that, for reproductive females; thermal stability, rather than high temperatures, determine roost selection. As such, wildland bats choose natural tree cavities that exhibit minimal variation compared to ambient conditions. However, when temperatures are low (March-April), bats may roost within cavities exposed to direct sunlight, which imparts the opportunity to maintain body temperature passively.

Misconception 9 | Bats will not roost over busy roadways (Erickson et al. 2002)

One of New Mexico’s most significant bridge populations spans the exit-ramp off Interstate Highway 25 (personal communication, n.d.). Although busy roadways may not be preferable, to dismiss these roosts would be imprudent and irresponsible.

Misconception 10 | Bats do not occupy transportation structures within northern states because “few are warm enough to meet bat needs.

Since the publication of ‘Bats in American Bridges’ (Keeley and Tuttle 1999), more than 47.8 percent of 23 northern states and three Canadian provinces have documented bridge specific bat colonies. At least two earlier publications, Bailey (1926) and Mumford and Cope (1958), provide occupancy reports from the northern states of Montana and Indiana, respectively. Furthermore, an inspection of 130 south-central Montana highway structures determined 60 percent occupancy rates – a frequency “as high or higher than in many surveyed regions farther south (Kurtz and Hendricks 2006).

3. Health and Safety Recommendation

3.1 Occupational Safety and Health

Bat surveys can be arduous, involve challenging locations, severe time schedules, extensive travel and many potential hazards. These risks must be adequately considered and accounted for during survey planning. High risk sites include construction sites, enclosed spaces, remote locations, sites with criminal activities and/or hostile residents. Transportation structures may traverse or parallel watercourses, roads or railway lines, which increase hazard potential. Surveyors should be trained in safe working practices including tackling steep ground, climbing on ladders, and water safety (assessing water flow, depth and currents) and in the use of equipment such as waders, lifejackets/ buoyancy aids, ladders and fiberscopes/borescopes.

Please employ appropriate caution and equipment to minimize safety risk. Guidance on safety and risk management-related issues can be found @ https://www.osha.gov/index.html.

3.1.1 Speciality Training

The following locations require advanced knowledge and use of specialist equipment. Specialist training courses or permits may be applicable.

Confined Spaces

Confined spaces have limited or restricted means for entry or exit and are not designed for continuous occupancy. Please consult the OSHA Standard for Confined Spaces.

At Height

Work at height means work in any place where, if there were no precautions in place, a person could fall a distance liable to cause personal injury. Take a sensible approach when considering precautions for work at height. Before working at height, consider these simple steps; avoid work at height where it is reasonably practicable to do so; where work at height cannot be avoided, prevent falls using the right type of equipment; and minimize the distance and consequences of a fall by using the right type of equipment where the risk cannot be eliminated. Please review OSHA Fall Protection Standards and Resources.

3.2 Zoonoses

3.2.1 Rabies

Individuals without experience and applicable permits should *not* capture or handle bats. This will eliminate the potential exposure and opportunity for rabies transmission.

3.2.2 Histoplasmosis

Bird and bat guano are classic reservoirs for *Histoplasma capsulatum*, the fungus that causes histoplasmosis, a systemic infection primarily of the respiratory tract. Outbreaks have been associated with demolition and earth-moving activities that aerosolize topsoil and dust (e.g., bridge reconstruction and demolition, jack- and air- hammering, waste disposal). Employees should wear personal protective equipment and employ dust-suppression techniques when working in areas potentially contaminated with bird and/or bat droppings (Huhn et al. 2005).

4. Decontamination Measures for White-nose Syndrome

WNS affects cave hibernating bats throughout eastern North America and adjacent Canada. This fatal disease continues to cause mass mortality and precipitous population declines. Previously common species throughout the northeastern United States are presently at risk of regional extirpation or extinction due to white-nose syndrome. “WNS has led to unprecedented mortality in several species of bats and may threaten more than 15 additional hibernating bat species if it continues across the continent” (Flory et al. 2012).

Pseudogymnoascus destructans, the causative agent of WNS, thrives at temperatures of 3-15 °C and > 90% relative humidity, conditions equivalent to bat hibernacula and bodies of hibernating bats. *P. destructans* affects bats by increasing the frequency and duration of arousals from hibernation.

Throughout the hibernation period, brief arousals to warm (euthermic) body temperatures are normal, but deplete fat stores. Typical arousal episodes span minutes or hours, with more frequent or lengthier arousal periods incurring significant energetic costs. Therefore, atypical arousal patterns due to white-nose syndrome prematurely deplete fat reserves crucial to overwinter survival. Additional WNS information available at http://www.whitenosesyndrome.org.

4.1 Decontamination Protocol

When activities involve close or direct contact with bats, their environments, and/or accompanying equipment and materials, please comply with decontamination protocols. Acceptable treatment options and supplemental information are available from http://www.whitenosesyndrome.org.

5. Evaluative Surveys

> "Perhaps more so than for any other wildlife issue, the potential effect on bats is independent of the scale of the operation concerned. Very small structures can be important to large populations of bats or to species of critical conservation importance. **All highway projects should take account of the potential presence of bats**" (Hinde 2008).

Any construction, improvement or maintenance project can directly and/or indirectly impact bats via habitat destruction and fragmentation (i.e., loss or severance of traditional travel routes), landscape modification (i.e., influencing the suitability of roosting, commuting and foraging habitat), disturbance, and alteration of environmental conditions. Thus, transportation authorities should consider bats as part of the environmental assessment of any construction, improvement or maintenance project, regardless of scale (Hinde 2008).

Landscape features (e.g., trees, vegetation, caves; commuting and foraging habitat) outside the existing structure are beyond the scope of this document. Please visit http://bati.institute for more information.

Surveys permits individuals to garner site-specific information by which to assess potential impacts and develop recommendations. Surveys are typically time-bound, once-only projects, although surveys may involve multiple visits or observations. These surveys are distinguishable from monitoring, which involves repeated sampling, either year-on-year or periodically, to evaluate whether a particular objective or standard has been attained (Bat Conservation Trust 2007).

Bat surveys should be undertaken at the appropriate time of year to collate the information required (e.g., summer surveys to detect maternity roosts, winter surveys to detect hibernating bats).

To ensure reliability, several visits across biological seasons should occur (i.e., minimum of 2-3 times per year). While bats are active throughout the night, peak activity occurs at dusk and before dawn; and surveyors should address bat activity during these time frames to provide comprehensive information of site utilization. The most effective detector survey period is June – August, which will provide information on maternity roosts. Earlier studies (April and May) and later studies (September) will yield information on alternative roosts (National Roads Authority 2006). Mist netting to capture and identify local bat species that may or may not be identifiable with bat detectors may be appropriate in certain circumstances (i.e., where detailed information on specific species is required, or where species of concern or high conservation value may occur). In enclosed areas (e.g., bridges), harp-trapping may be employed to confirm the presence of species. (Please review Section 5.3 Survey Methodologies).

5.1 Surveyor Qualifications and Considerations

In the United States, there are no coincident standards nor specific qualifications to perform bat surveys. However, the assessment of bat presence requires expertise, experience and objectivity. "It is comparatively easy to determine use of a site by bats, but absence is more difficult to prove. It requires greater effort to demonstrate beyond reasonable doubt that bats are not present or likely to be present (Bat Conservation Trust 2007)."

Surveyors must be mindful and respectful, to prevent roost abandonment and accidental injury to or mortality of bats. Additionally, the surveyor must be competent in identifying bats (may require capture and handling to determine/confirm species) and their respective habitat.

To independently and competently conduct professional bat surveys, an individual should possess the following (Bat Conservation Trust 2012);

<u>Expertise</u>

- species status, distribution, and conservation threats

- annual biological cycle and life history characteristics
- species-specific and seasonal requirements of roosts and the various natural features and anthropogenic structures available as roosts
- variety of available survey techniques, their appropriate application and limitations
- seasonality and conditions and their influence on surveys
- health and safety issues (e.g., unsafe structures, working at night)
- techniques to avoid and minimize negative impacts

<u>Experience</u>

- ability to identify sign(s), locate roosts and indicate probable species and roost type (e.g., maternity roost, night roost)
- ability to quantify potential impact(s) and deliver site- and species-specific recommendations for mitigation
- ability to capture, handle and/or transport individual bat(s) humanely and proficiently
- identify individual species and confidently age, sex and assess reproductive status
- communicate information and recommendations clearly and concisely

5.2 Basic Survey

An exploratory survey to establish presence/absence, assess probability or severity of impact(s), and acquire information to recommend mitigation and/or compensation measures may include;

<u>General information</u>

- date,
- surveyor name(s),
- site description (i.e., descriptive information and coordinates),
- proposed activity (e.g., construction, demolition, repair, maintenance),
- direct evidence of current or prior occupancy (e.g., guano, carcasses, cobweb-free entrances to voids, scratches, urine stains),
- species present,
- roost information including type (e.g., diurnal, nocturnal, maternity, hibernaculum), location, characteristics (e.g., crevice, swallow nest, drainpipe),
- intensity (e.g., number of bats, time and duration of use),
- roost substrate and dimensions,
- surrounding habitat (e.g., residential, agricultural, woodland), and
- conditions beneath roost (e.g., bare ground, railroad, watercourse, 4-lane highway).

Photographs are invaluable to conveying both structure-specific details and evidence of occupancy. It is recommended that photographs are taken to support written documentation. Please be mindful and responsible when photographing bats.

<u>Built structure information</u>

- structure design (e.g., type, number of spans, height),
- structure material (e.g., concrete, metal, timber), and
- location and description of current, prior or potential roost sites.

Advanced surveys are beyond the scope of this document. Additional information and resources including progressive techniques and methodologies are available at http://www.bati.institute/best-management-practices/.

5.3 Survey Methodologies

Methods may typically involve one or more of the following;

5.3.1 Non-invasive

5.3.1.1 Visual

Bats may use transportation structures at any time of the year and timing of work must take into account bat activity at each site. It is not unusual for several bat species to use different parts of the same structure.

Structures often conceal bats within features not visible from the ground.

Bridges

Systematically search for direct evidence of occupancy. Inspect key features and locations likely to support bats.

Roost locations may include;

- open beams,
- structural fissures (e.g., cracked or spalled concrete, damaged or split beams, split or damaged timber railings),
- crevices (e.g., expansion joints, space between parallel beams, spaces above supports piers, space between adjacent concrete parapets/guardrails),
- alternative structures (e.g., drainage pipes, bolt cavities, open sections between support beams), and
- nests. When abandoned or unoccupied, nests provide ancillary roost habitat for bats worldwide. Occupancy rates can approach 39 percent (Jackson et al 1982). Bats that exploit *Hirundo rustica* (barn swallow) nests lay nearly prostrate within the nest cup and those within *Petrochelidon pyrrhonota* (cliff swallow) nests (gourd-shaped enclosed structures) are typically concealed and undetectable without a borescope or fiberscope.

Culverts

In opposition to bridges, which frequently have structurally-integral locations amenable to bats (e.g., drainage pipes, expansion joints), roosting locations within culverts predominantly overlay structural defects. Conducting routine maintenance (e.g., concrete patches, epoxy joint patch seals), without an appropriate, preliminary survey, can easily entomb or kill bats.

Roost locations may include;

- walls,
- structural fissures,
- transition points between culvert sections (e.g., where a concrete culvert transitions to a metal culvert, where a box culvert transitions to a circular culvert),
- alternative structures (e.g., drainage pipes), and
- nests, particularly *Hirundo rustica* and *Petrochelidon pyrrhonota* nests.

5.3.1.2 Emergence and Re-entry Surveys

Where potential presence is high, but cannot be confirmed, surveyors can perform dusk emergence and/or dawn re-entry surveys. Emergence and re-entry surveys can provide additional information (e.g., number of bats, species, flight paths to and from roost) to help determine the importance of an identified roost and potential significance of any impacts. Emergence surveys should commence > 15 minutes before sunset and continue for two hours after sunset

(Bat Conservation Trust 2007).
Dawn re-entry surveys can help detect summer roosts, particularly those of species who form small colonies, emerge late or are difficult to identify with bat detectors. Emergence and re-entry surveys should occur when bats are most active (April – September).
Dawn re-entry surveys of maternity roosts are oftentimes most successful July – August when re-entry attempts by newly volant juveniles are both obvious and of extended duration. These surveys should commence > 90 minutes before sunrise, as *Myotis* spp. typically return to roost sites earlier than other species.

5.3.1.3 Acoustic Surveys (active and passive)

Passive acoustic monitoring can identify periods and locations of peak activity levels. Automated activity surveys are non-intrusive and can help determine bat activity over lengthy time intervals; particularly winter (November – February), when bat activity is irregular. For winter activity, a minimum of two, two-week surveys sessions are recommended, one of which should occur between December and February (Bat Conservation Trust 2007). Various exogenous and endogenous factors influence activity patterns, which can further vary by habitat, season, species and locality (e.g., cool temperatures and precipitation typically suppress bat activity).

In more exceptional cases it may also be appropriate to use the more invasive survey techniques described below. Surveyors should employ non-invasive survey methodologies first and foremost. **The decision to employ invasive techniques may occur only where essential information cannot be acquired with less intrusive methods and must consider bat welfare and time-of-year vulnerability.**

5.3.2 Invasive

- capture (i.e., hand nets, mist nets and harp traps)

Capturing bats via netting and harp traps can provide valuable information relative to species identification, sex determination and breeding status.

Nonetheless, these techniques are invasive and warrant careful consideration. The minimum number of visits necessary to obtain the appropriate information will be situation and objective-dependent. **Please prioritize animal welfare. If any method of capture causes, or appears to cause, distress or harm, please cease activities immediately and solicit further advice.**

Time surveys to minimize the potential capture of parturient or lactating females; heavily pregnant bats may give birth or abort their fetus while captive (Finnemore and Richardson 2004). Please become familiar with your state's endemic bat species and their respective maternity seasons, which vary by species and region. Conservatively, refrain from conducting capture surveys from late May to mid-July, unless exceptional, and justifiable, circumstances exist.

These aforementioned methods should only be undertaken by specialist surveyors with prior demonstrable experience.

5.4 Appropriate Time Schedules

Chiropteran ecology and ethology influence both timings of surveys and therefore, operational activities (See Figure 1 for an overview of the bats' annual cycle). Bats exhibit considerable diversity and plasticity – both within and between species. Consequently, the annual cycle

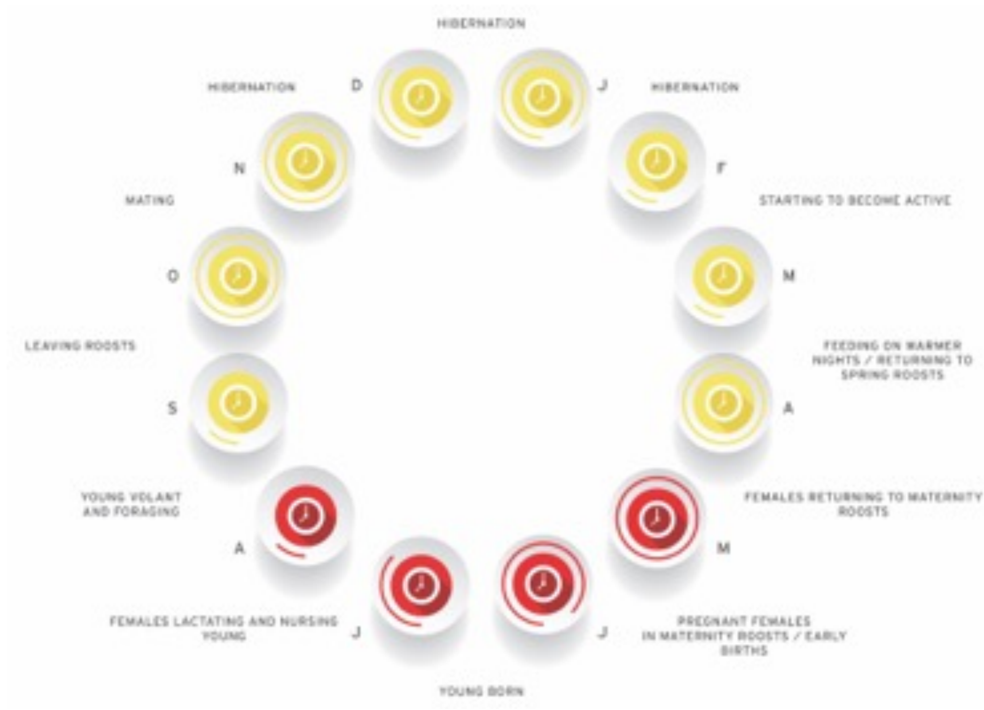


Figure 1. Overview of bats' annual life cycle. Yellow represents 'Caution,' bats may be vulnerable depending on species and geographical location; red indicates 'Stop,' bats are exceptionally vulnerable to disturbance.

may vary. These biological milestones can further vary geographically; thus, optimal timings must develop from practical experience and familiarity with local species. All bat surveys should be undertaken at the appropriate time of year to collate the information required (e.g., summer surveys to detect maternity roosts and winter surveys to detect hibernating bats).

5.5 Assessment

An evaluation of survey results and supplemental information are necessary to assess the importance of existing habitats/features and the magnitude of foreseeable impacts (e.g., disturbance, mortality). Assessments should include relative impact(s), their influence on the integrity and conservation status of relevant bat communities and recommendations for mitigation measures.

5.5.1 Disturbance

Installation of temporary or permanent lighting can introduce barriers to movement, sever foraging areas, discourage emergence or precipitate roost abandonment. Roost adjacent lighting may modify microclimatic conditions (i.e., humidity or temperature) or cause disturbance, which may precipitate roost abandonment. Similarly, maintenance projects can potentially disturb roosting bats via employment of inappropriate methodologies or materials, or modification of roost parameters.

5.5.2 Mortality

Mortality may occur from reactive behavior, traffic differences, or accidental roost destruction. Some species may continue to follow severed commuting routes, endangering those individuals that traverse roadways. Anecdotal observations (Bickmore et al. 2003 as cited in \\\

Hinde 2008) indicate that “air turbulence caused by fast and large road traffic can suck nearby bats into the path of oncoming vehicles.” Traffic inflation, resulting from improvements or new construction, may cause significant mortality, particularly when adjacent to nursery roost(s), with inexperienced juveniles most vulnerable. Mortality rates increase during July and August, coincident with the occurrence of volant young; and late September – early October, which may correlate to mating and autumnal migration (Gaisler et al. 2009, Lesiński et al. 2011, Medinas et al. 2012).

5.6 Documentation

An assessment report should include,

- information from collective survey(s) including existing roosts, species present, et cetera and their relative importance;
- the potential effects of the relevant operational activity;
- recommendations for mitigation and an explanation and/or justification for selecting these recommendations;
- recommendations to prevent, reduce and as fully as possible offset any significant adverse effects; and
- monitoring methods and protocols, if applicable.

6 Mitigation Measures

This section provides mitigation measures by which to avoid, minimize and if possible, remedy adverse effects. Where elimination of adverse effects is not possible, measures can be implemented to alleviate the severity of impacts. Species differ relative to sensitivity and exploitation (e.g., roost choice, travel corridors, flight heights, foraging strategy) of the landscape. Therefore, any mitigation measures should endeavor to accommodate the species with the most sensitive requirements or conservation status. Mitigation measures must be project-specific, and proportionate to the importance of population(s) and scale of potential impacts.

6.1 Avoidance

Avoid disturbing sites while bats are present whenever possible. Avoid permanently destroying/altering bat roosts whenever possible. Avoidance of an area, structure, or site with bat presence remains the best mitigation measure for the protection of bats. Many roosts are seasonal and therefore, operational activities may occur within the period when bats are absent.

Optimum season for operational activities for different roost types are as follows;

- for maternity and nursery roosts, conduct activities 1 October to 1 May
- for summer roosts, conduct activities 1 September to 1 May
- for hibernacula, conduct activities 1 May to 1 October
- for swarming / mating sites, conduct activities 1 November to 1 August

Please become familiar with your state’s endemic bat species and their specific biological seasons, which vary geographically.

6.2 Minimization

6.2.1 Appropriate Time Schedules

Bennett et al. (2008) recommend an inspection interval of 3-5 times annually to determine use. Lengthy time intervals between biological investigations and operational activities increase the probability of occupancy; and therefore, the unreliability of those evaluations.
Maternity colonies form from April onwards and remain relatively cohesive through mid- to late August. Young, born May-July, are non-volant (i.e., not capable of flight or evasive action, wholly dependent on mothers) for several weeks and thus, are extremely vulnerable to disturbance by human activities (e.g., restoration, reinforcement or demolition of structures).
Please become familiar with your state's endemic bat species and their respective maternity seasons, which vary by species and region. Contact your state wildlife agency to learn specific details about time-of-year restrictions, regulations, sensitive species (T & E species, state species of concern) statutes and/or requisite permits. Please note, the minimum standards provided here may not be sufficient to avoid, minimize, or mitigate impacts to listed bat species.

6.2.1.1 Wildlife Exclusion

Specific mitigation measures to exclude must be in situ prior to demolition or maintenance activities.

If applicable, exclusion may occur September - March. Exclusion should not occur April – August when bats are exceptionally vulnerable to disturbance. If hibernating bats are present, exclusion can not occur late November – early March.

Any exclusion product can cause disturbance, harm or fatality if improperly installed. It is the responsibility of the hiring agency to ensure anyone performing these activities can conduct exclusion activities, including eviction, appropriately and humanely.

Please respect wildlife. Do not poison, pressure wash, trap, relocate, or in any other manner harm, harass or kill bats. These are ineffective, unnecessary techniques, potentially illegal, and do not comply with acceptable standards.

6.2.1.2 Maintenance

Maintenance activities include, but are not limited to, cleaning, preventative maintenance to preserve and lengthen service life, technical and specialized repairs and stream channel maintenance. These activities may involve the operation of support vehicles and equipment, pavement repair, welding and grinding operations, and associated pollutants, which may impact nearby bat colonies.

Minor maintenance activities typically have minor or no impact on bats. However, more substantial maintenance operations, including replacement or strengthening of structures above water level, should entail a bat assessment (Bat Conservation Ireland 2010). If bats are present, exclusion procedures should be implemented prior to maintenance activities.

Some maintenance activities (e.g., surface treatments including chip sealing, crack filling, crack sealing, patching) can kill, entomb bats or cause the abandonment of non-volant young. Additionally, these activities can create excessive noise, vibrations, and modify thermal conditions of roosts; and consequently, may promote roost abandonment. If bats are present, exclusion procedures should be implemented prior to maintenance activities.

Night-time maintenance activities can affect bats. Light, odors and noise can delay or discourage bats from emergence, or potentially, cause site abandonment. Activities adjacent to roosts should be avoided, especially when bats are most vulnerable (mid- March – end of July). If operations are inevitable, we recommend the installation of very localized lighting in the worksite zone, avoiding surrounding areas to reduce the barrier effect. The temporary erection of noise barriers and/or light screens may also be considered. Temporary infrastructure (e.g., stockpile areas, roads for construction traffic) should be constructed at a distance from roosts (Sétra et al. 2009).

Maintenance activities which involve the replacement of bridge components with contrastive products may modify roost microclimate, dimensions, illumination, et cetera; and consequently, may promote roost abandonment.

7 Literature Cited

American Society of State Highway and Transportation Officials [AASHTO]. 2008. <http://environment.transportation.org>.

Bailey, V. 1926. A Biological Survey of North Dakota. North American Fauna, 49,1-226.

Bat Conservation Ireland [BCIreland]. 2010. Bats and waterways. Guidance notes for planners, engineers and developers. <http://www.batconservationireland.org/pubs/reports/BCI_Guidelines_waterways.pdf>.

Bat Conservation Trust. 2007. Bat surveys: good practice guidelines. Bat Conservation Trust, London. 87 pp.

Bat Conservation Trust. 2012. Professional Training Standards for Ecological Consultants. Bat Conservation Trust, London. 29 pp.

Bender, M. J., S. B. Castleberry, D. A. Miller, and T. Bently Wigley. 2010. Use of culverts as diurnal roost by bats in Butler Co, Alabama. Journal of the Alabama Academy of Science 81(3-4), 204-210.

Bennett, F. M., S. C. Loeb, M. S. Bunch, and W. W. Bowerman. 2008. Use and selection of bridges as day roosts by Rafinesque's big-eared bats. Am. Midl. Nat., 160(2), 386-399.

Benson, S. B. 1947. Comments on migration and hibernation in *Tadarida mexicana*. Journal of Mammalogy, 28, 407-408.

Bickmore, C. 2003. Catherine Bickmore Associates. Review of work carried out on trunk road network in Wales for bats. A report produced on behalf of the Transport Directive, Welsh Assembly Government & Countryside Council for Wales.

Boonman, M. 2011. Factors determining the use of culverts underneath highways and railway tracks by bats in lowland areas. Lutra, 54(1), 3-16.

Boulay, P., and R. Goggans. 1999. Survey of bat use of bridges in the Willamette Valley. Corvallis, Oregon, Oregon Department of Fish and Wildlife.

Cel'uch, M., and Ševčík. 2008. Road bridges as roosts for noctules (*Nyctalus noctula*) and other bat species in Slovakia (Chiroptera: Vespertilioniade). Lynx (Praha), n.s., 39(1), 47-54.

Ellison, L. E., T. J. O'Shea, M. A. Bogan, A. L. Everette, and D. M. Schneider. 2003. Existing data on colonies of bats in the United States: summary and analysis of the U.S. Geological Survey's Bat Population Database. In O'Shea, T. J., and M. A. Bogan, eds. Monitoring trends in bat populations of the United States and territories: problems and prospects. U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report, USGS/BRD/ITR-2003-0003, 274 pp.

Erickson, G. A., E. D. Pierson, W. Rainey, and P. Brown. 2002. Hitchhikers guide to bat roosts. Bat and Bridges Technical Bulletin, California Department of Transportation, Sacramento, California.

Flory, A. R., S. Kumar, T. J. Stohlgren, and P. M. Cryan. 2012. Environmental conditions associated with bat white-nose syndrome mortality in the northeastern United States. Journal of Applied Ecology, 49, 680-689.

Finnemore, M., and P. W. Richardson. 2004. Catching bats. *In* Mitchell-Jones, A. J., and A. McLeish, eds. 3rd Edition Bat Workers' Manual. pp. 41-48. Joint Nature Conservation Committee.

Gaisler, J. Z. Řehák, and T. Bartonička. 2009. Bat casualties by road traffic (Brno-Vienna). Acta Theriologica, 54(2), 147-155.

Hendricks, P., J. Johnson, S. Lenard, and C. Currier. 2004. Use of a bridge for day roosting by the hoary bat, *Lasiurus cinereus*. Canadian Field-Naturalist, 119(1), 132-133.

Hinde, D. 2008. Nature conservation advice in relation to bats. Highways England Interim Advice Note116/08. 57 pp. <http://www.standardsforhighways.co.uk/ians/pdfs/ian116.pdf>.

Huhn, G. D., C. Austin, M. Carr, D. Heyer, P. Boudreau, G. Gilbert, T. Eimen, M. D. Lindsley, S. Cali, C. S. Conover, and M. S. Dworkin. 2005. Two outbreaks of occupationally acquired histoplasmosis: more than workers at risk. Environmental Health Perspectives, 113(5), 585-589.

Jackson, J. A., B. J. Schardien, C. D. Cooley, and B. E. Rowe. 1982. Cave myotis roosting in barn swallow nests. Southwestern Naturalist, 27(4), 463-464.

Keeley, B. W., and M. D. Tuttle. 1999. Bats in American bridges. Bat Conservation International, Inc., Austin, Texas. Resource Publication, 40 pp.

Kunz, T. H., and D. S. Reynolds. 2003. Bat colonies in buildings. *In* O'Shea, T. J., and M. A. Bogan, eds. Monitoring trends in bat populations of the United States and territories: problems and prospects. U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report, USGS/BRD/ITR-2003-0003, 274 pp.

Kurtz, C. and P. Hendricks. "Of bats and bridges." Montana Naturalist, Winter 2005-06. p.6. Print
Lance et al. 2001

Lesiński, G., A. Sikora, and A. Olszewski. 2011. Bat casualties on a road crossing a mosaic landscape. European Journal of Wildlife Research, 57(2), 217-223.

Limpens, P., P. Twisk, and G. Veenbaas. 2005. Bats and road construction. Ministerie van Verkeer en Waterstaat, Rijkswaterstaat, Dienst Weg-en Waterbouwkunde. 28 pp.

Loeb, S. C., T. J. Rodhouse, L. E. Ellison, C. L. Lausen, J. D. Reichard, K. M. Irvine, T. E. Ingersoll, J. Coleman, W. E. Thogmartin, J. R. Sauer, C. M. Francis, M. L. Bayless, T. R. Stanley, and D. H. Johnson. 2015. A plan for the North American Bat Monitoring Program (NABat). Gen. Tech. Rep. SRS-208. Asheville, NC; U.S. Department of Agriculture Forest Service, Southern Research Station. 100 pp.

MacGregor, J. R., and J. D. Kiser. 1999. Temperature variation at a maternity roost for *Myotis leibii* in a concrete bridge in eastern Kentucky. Abstract of a paper presented at the Fourth Annual Meeting of the Southeastern Bat Diversity Network, Wytheville, Virginia, February 1999.

Martin, C. O., R. F. Lance, and C. H. Bucciantini. 2005. Collisions with aircraft and use of culverts under runways by bats at U.S. Naval Air Station, Meridian, Meridian, Mississippi. Bat Research News, 46(2), 51-54.

Martin, C. O., A. S. McCartney, D. Richardson, A. W. Trousdale, and M. S. Wolters. 2011. Rafinesque's big-eared bat (Corynorhinus rafinesquii) in Mississippi: distribution, current status, and conservation needs. In Loeb, S. C., M. J. Lacki, and D. A. Miller, eds. 2011. Conservation and management of eastern big-eared bats: a symposium. Gen. Tech. Rep. SRS-145. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 157 p.

Medinas, D., J. T. Marques, and A. Mira. 2012. Assessing road effects on bats: the role of landscape, road features, and bat activity on road-kills. Ecol Res, 28, 227-237.

Mumford, R. E., and J. B. Cope. 1958. Summer records of Myotis sodalis in Indiana. Journal of Mammalogy, 39, 586-587.

National Roads Authority. 2006. Guidelines for assessment of ecological impacts of national road schemes. National Roads Authority, Dublin. 56 pp.

Phillips, C. J., and J. K. Jones, Jr. 1971. A new subspecies of the long-nosed bat, Hylonycteris underwoodii, from Mexico. Journal of Mammalogy, 52(1), 77-80.

Sandel, J. K., G. R. Benatar, K. M. Burke, C. W. Walker, T. E. Lacher, Jr., and R. L. Honeycutt. 2001. Use and selection of winter hibernacula by the eastern pipistrelle (Pipistrellus subflavus) in Texas. J of Mammalogy, 82(1), 173-178.

Sétra, CETE de l'Est, and CETE Normandie-Centre. 2009. Bats and road transport infrastructure - threats and preservation measures. Sétra Information Notes, Economics Environment Design Serie n 91, 22 pp.

Smith, H. J., and J. S. Stevenson. 2013a. Linking conservation and transportation: a bats in bridges report. New Mexico Department of Transportation Task No. 5372-33. <http://issuu.com/rdwildlifemanagement/docs/rdwm_____nmdot_magazine_39e2c4474c50a4/0. 95 pp.

Smith, H. J., and J. S. Stevenson. 2013b. The thermal environment of a concrete bridge and its influence on roost site selection by bats (Mammalia: Chiroptera). Proceedings of the 2013 International Conference on Ecology and Transportation. <http://www.icoet.net/ICOET_2013/proceedings.asp>.

Smith, H. J., and J. S. Stevenson. 2016. [An investigation of culvert occupancy by New Mexican microchiropterans]. Unpublished raw data.

Walker, C. W., J. K. Sandel, R. L. Honeycutt, and C. Adams. 1996. Winter utilization of box culverts by vespertilionid bats in southeast Texas. Texas Journal of Science, 48(2), 166-168.

Appendix 1 Scientific and common names of the 47 bat species that inhabit the United States

Scientific Name	Common Name
Antrozous pallidus	pallid bat
Artibeus jamaicensis	Jamaican fruit-eating bat
Choeronycteris mexicana	Mexican long-tongued bat
Corynorhinus rafinesquii	Rafinesque's big-eared bat
Corynorhinus townsendii	Townsend's big-eared bat
Eptesicus fuscus	big brown bat
Euderma maculatum	spotted bat
Eumops floridanus	Florida bonneted bat
Eumops perotis	greater bonneted bat
Eumops underwoodii	Underwood's bonneted bat
Idionycteris phyllotis	Allen's big-eared bat
Lasionycteris noctivagans	silver-haired bat
Lasiurus blossevillii	western red bat
Lasiurus borealis	eastern red bat
Lasiurus cinereus	hoary bat
Lasiurus ega	southern yellow bat
Lasiurus intermedius	northern yellow bat
Lasiurus seminolus	seminole bat
Lasiurus xanthinus	western yellow bat
Leptonycteris nivalis	Mexican long-nosed bat
Leptonycteris yerbabuenae	lesser long-nosed bat
Macrotus californicus	California leaf-nosed bat
Molossus molossus	Pallas' mastiff bat
Mormoops megalophylla	Peter's ghost-faced bat
Myotis auriculus	southwestern myotis
Myotis austroriparius	southeastern myotis
Myotis californicus	California myotis
Myotis ciliolabrum	western small-footed myotis
Myotis evotis	long-eared myotis
Myotis grisescens	gray myotis
Myotis keenii	Keen's myotis
Myotis leibii	eastern small-footed myotis
Myotis lucifugus	little brown myotis

Myotis melanorhinus	dark-nosed small-footed myotis
Myotis occultus	Arizona myotis
Myotis septentrionalis	northern myotis
Myotis sodalis	Indiana myotis
Myotis thysanodes	fringed myotis
Myotis velifer	cave myotis
Myotis volans	long-legged myotis
Myotis yumanensis	Yuma myotis
Nycticeius humeralis	evening bat
Nyctinomops femorosaccus	pocketed free-tailed bat
Nyctinomops macrotis	big free-tailed bat
Parastrellus hesperus	canyon bat, western pipistrelle
Perimyotis subflavus	tri-colored bat
Tadarida brasiliensis	Mexican free-tailed bat

Appendix 2

Image Gallery | Typical indicators of bat presence
Visit http://www.bati.institute/gallery/ for more images

guano accumulation below roosts (between box beams)

guano accumulation below roosts (midline expansion

urine crystallization on edge of roost

Myotis spp. day roosting on open beam

Myotis spp. day roosting in clogged drainage pipe

Tadarida brasiliensis maternity colony with pups in expansion joint

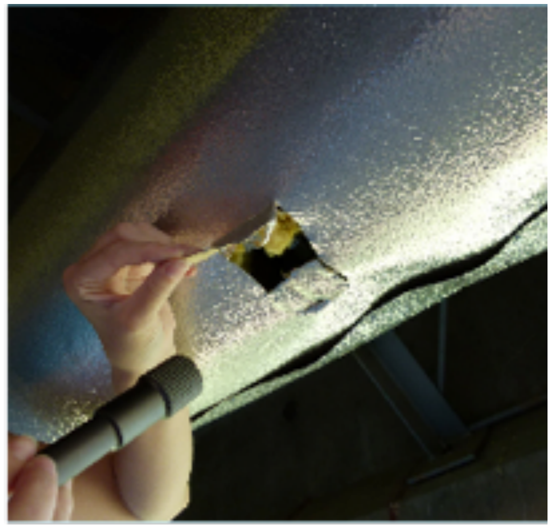
Myotis spp. colony roosting in timber bridge between double beams

Myotis yumanensis exploiting concrete spall

Myotis spp. maternity colony with pups in expansion joint

Migrating *Tadarida brasiliensis* colony using bridge as transient roost site

Drainage pipe roost



Bats roosting within ‘bolt cavity’ in insulated pipe

Roosting in void created by concrete spall

Myotis spp. roosting in void created by concrete spall

6.35 mm diameter roost opening

bat prostrate in wasps’ nest

bats roosting inside intact swallow nests

bats roosting in pipe collar

bats roosting behind blue insulation board

although urine staining is noticeable, a cursory view of a metal-clad concrete bridge would be deemed unusable with no further inspection

bats roosting between beams and deck

individual bat behind timber guardrail

bats roosting between pier and deck

Foam sealant was used to exclude bats from obvious roost locations (between parallel beams). However, incomplete exclusion attempts allow the potential for occupancy (please see images below).

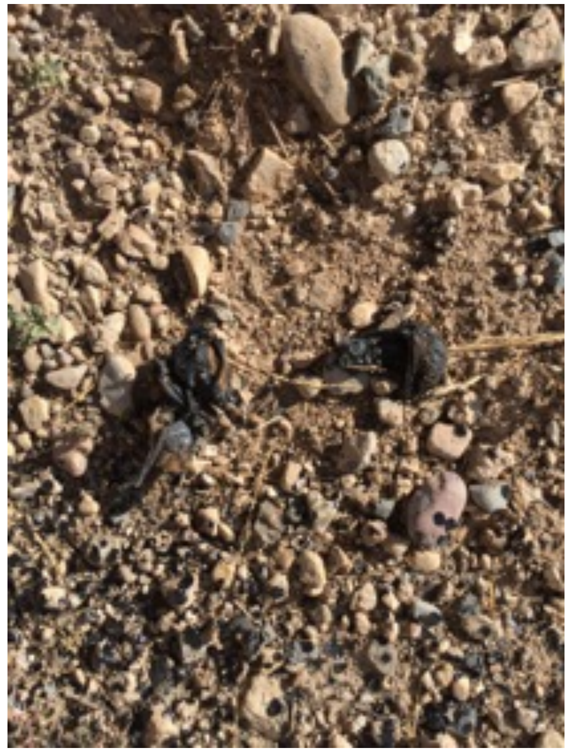
Foam did not completely fill the crevice between parallel beams, which still provides amenable roosting space for individual bats (particularly important for T&E species, whereby single bats are of high conservation concern).

Although exclusion was “completed,” (left and above) this roosting location (maternity colony roosting in space between road deck and timber beams) was overlooked.

Liquid asphalt seeping through parallel beams while bats were present

Above and below; consequences of applying hot liquid asphalt during hibernation season (*T. brasiliensis* colony)

Application of liquid asphalt killed Myotis colony that were roosting in bridge

Bridge workers replacing elastomeric seal directly above bat roosts. Such maintenance activities should occur when bats are absent to prevent abandonment of roost and/or young.