Best Management Practices for Bats in British Columbia

Chapter 9: Bridges

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Executive Summary

The British Columbia Ministry of Environment and Climate Change Strategy has developed this document to provide helpful guidance to bridge managers, transportation infrastructure developers, other resource developers, consultants, and biologists on how to minimize impacts on bats due to bridge maintenance, repair, and replacement, as well as installation of new bridges that may provide bat habitat in British Columbia. Use of these Best Management Practices demonstrates due diligence toward the protection of bats and their habitats where developments provide roosting features for bats.

"Best Management Practices Guidelines for Bats in British Columbia: Chapter 9: Bridges" is one chapter of a larger strategy document that identifies several resource sectors in British Columbia that are most likely to have impacts on bats and their habitats. Chapter 1: "Introduction to Bats of British Columbia" provides a review of bat species and their distribution and ecology in British Columbia, and should be reviewed in conjunction with the industry/activity-specific Best Management Practices guidance in later chapters. These Best Management Practices represent "guidelines" and are not provincially legislated. In some cases, proponents will need to give priority to other legislation in conjunction with implementation of the Best Management Practices for bats (e.g., the *Migratory Birds Convention Act*, British Columbia *Wildlife Act* and *Fisheries Act*, and/or any legislation specific to human health and safety). The expectation is that proponents will use these Best Management Practices to the best of their ability to conserve provincial bat populations.

Each industry-/activity-specific chapter follows a similar structure. Section 1 highlights particular aspects of bat ecology, behaviour, and distribution that may be affected by a specific industry/activity; for example, mining, development of wind power, or caving. Section 2 describes the activities associated with a specific industry and the potential impact those activities may have on bats and their habitats. Section 3 outlines Best Management Practices. Section 4 lists monitoring and reporting priorities. Section 5 outlines knowledge gaps and information needs to improve adaptive management for bats in specific industries/activities.

Some of the issues discussed in this document are subject to ongoing research. All activities related to assessing the quality of bat habitat or the impact of activities on bats should engage an experienced bat biologist who is qualified to conduct bat surveys.

Thirteen of the 15 bat species in British Columbia have roosting preferences that include caves, rock or tree crevices, and cracks or surface openings that may be mimicked by bridge structures. Many bats use crevices as maternity or night roosts during the summer, and for swarming as part of their breeding behaviour in autumn. Human activity in and around crevice habitat on bridges has the potential to negatively affect bats. This chapter outlines the issues associated with bat crevice habitat, and Best Management Practices for bridge management to minimize impacts on bats.

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Front page photo: The Camelsfoot Bridge in Lillooet, B.C. is home to a maternity colony of Myotis bats. Photo courtesy of I. Routley.

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1 Introduction

1.1 Purpose/scope

Crevices and sheltered cavernous features provide important protected, safe, roosting habitat for many of British Columbia's bat species throughout the year. Bridges can provide excellent roosting habitat for bats by offering crevice features that are similar to those found in trees, talus, and rocky outcrops.

Bridges need to be maintained, repaired, and sometimes replaced or expanded. Activities such as construction, power washing, and repair may impact bats. Bridges and roadways may require lighting for safety purposes, which can also affect bats and their habitats.

This chapter outlines Best Management Practices for bridges that are used by bats in British Columbia, including recommended timing of maintenance activities. It also describes the impacts of lighting on bats and provides an initial approach to inventorying bats that use bridges. Inventories will help both biologists and bridge managers understand patterns of bridge use by bats and will contribute to improving guidance on protecting bats.

1.2 How to use this document

*"*Best Management Practices Guidelines for Bats in British Columbia: Chapter 9: Bridges" is one chapter of a larger strategy document that has been written for the resource sectors in British Columbia that are most likely to have impacts on bats and their habitats. Chapter 1 provides an introduction to the bats of British Columbia, along with in-depth information on bat ecology, to set the context for the following resource sector-specific chapters. Chapter 1 should be read in conjunction with each sector-specific chapter.

This guidance document[1] has been developed for bridge managers (including those who are working with the Province and the Ministry of Transportation and Infrastructure, municipal bridge managers, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development [FLNRORD], and railway bridge managers), and consultants who may be responsible for conducting the work. It summarizes currently available scientific information on potential effects of activities on bats that use bridges, and provides protocols to avoid and minimize effects on bats.

All activities related to assessing the quality of bat habitat or the impact of activities on bats should involve an experienced bat biologist with specialized knowledge and training because bats have unique adaptations and behaviours.

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[1] A set of recommended or suggested methods or actions that should be followed in most circumstances to assist administrative and planning decisions and their implementation in the field. Guidelines may consist of policy statements, procedures, or checklists. They are provided as a broad framework of recommended actions to be taken, and therefore provide some flexibility in decision-making. Note that guidelines cannot, by definition, be mandatory; such actions are prescribed by regulations or rules (Dunster and Dunster 1996).

NOTE: If there are known permanent bat roosts in anthropogenic or natural features that are not part of the bridge or bridge-related structures (e.g., mine, cave, long-duration tree roost), refer to the relevant Best Management Practices guidelines: https://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12460.

1.3 Objectives

The objectives of this document are to:

1. describe the ecology and distribution of bats that use bridges, how they use bridges, and why bridges are important for them (Section 1);
2. explain how bridge maintenance, repair, removal or alteration, construction, and lighting may affect populations of bats that use bridges (Section 2);
3. describe Best Management Practices (BMPs) guidelines to avoid and minimize impacts on bats due to bridge maintenance, repair, removal or alteration, construction, or lighting (Section 3);
4. describe recommended processes for reporting information about bats and bridges (Section 4); and
5. list areas of research and inventory that are necessary to improve bridge management for bats and assess the effectiveness of the BMPs (Section 5).

Section 6 provides definitions of technical terms used in this chapter; Section 7 lists the references cited, and provides links to additional information on bats.

1.4 Bat use of bridges in British Columbia

Twelve of the 15 bat species that occur in British Columbia (Table 1) have roosting preferences that include crevices, which may occur in caves, rocks, and other geological formations, or in trees (see Chapter 1 for additional information on roosting preferences). Many of British Columbia's bat species use bridge crevices in some part of their range (Table 1). Accidental species (defined as species occurring infrequently and unpredictably, outside their usual range [B.C. MOE 2020]) are also considered in this document because recent research indicates that they may be present in British Columbia and may use bridges (Ommundsen et al. 2017).

There are provincial and federal laws that protect bats and may apply to bats in bridges. The British Columbia *Wildlife Act* protects all bat species in British Columbia from being killed, wounded, captured, hunted, trapped, or transported. For a complete description of all the British Columbia legislation that applies to bats and their habitats, refer to Chapter 1: "Best Management Practices for Bats: Introduction to Bats of British Columbia." A *Wildlife Act* permit is required for any inventory work that includes the capture or handling of wildlife, which should be undertaken only by a bat specialist. A number of British Columbia bat species are listed under the federal *Species at Risk Act* (SARA) and are on the List of Wildlife Species at Risk (Schedule 1 of SARA) (Table 1). Once a species is listed under SARA, prohibitions against harm apply to the species on federal lands. A federal permit is needed prior to engaging in any activity that may affect a SARA-listed species or its critical habitat on federal lands. If the Province does not provide protection for listed species on other lands, the federal government may invoke a "safety net" order under SARA.

Table 1. Roosting preferences of British Columbia's bat species, and their status (Keeley and Tuttle 1999; Erickson et al. 2002; Johnston et al. 2004; Smith and Stevenson 2015)

Species	Status (provincial/ federal)[a]	Uses bridges?	Summer roost: crevice or cavity[b]	Roost type in bridge: maternity(M), night (N), or day (D)
Pallid Bat *Antrozous pallidus*	S2 – Red/ Threatened	Frequently	Cliffs, rock outcrops, crevices, caves, bridges	M/N/D
Townsend's Big-eared Bat *Corynorhinus townsendii*	S3S4 – Blue	Sometimes	Cliffs, caves, trees, buildings, bridges	May use if bridge has "cave-like" structure, M/N/D
Big Brown Bat *Eptesicus fuscus*	S5 – Yellow	Frequently	Cliffs, rock crevices, trees, buildings, bridges	M/N/D
Spotted Bat *Euderma maculatum*	S3S4 – Blue/ Special Concern	Not known (uses rock crevices)	Cliffs	Not likely any, but unknown
Silver-haired Bat *Lasionycteris noctivagans*	S4S5 – Yellow	Rarely	Trees	N (possibly)
Hoary Bat *Lasiurus cinereus*	S4S5 – Yellow	No	Trees (open foliage roost)	n/a
Eastern Red Bat *Lasiurus borealis*	SU – Unknown	No	Trees (open foliage roost)	n/a
California Myotis *Myotis californicus*	S4S5 – Yellow	Sometimes	Crevices in rock outcrops, caves, cliffs, trees, bridges	M/N/D
Western Small-footed Myotis *Myotis ciliolabrum*	S2S3 – Blue	Sometimes	Crevices in rock outcrops and cliffs, talus slopes, boulders, bridges	M/N/D
Long-eared Myotis *Myotis evotis*	S5? – Yellow	Sometimes	Cliffs, talus slopes, rock outcrops, crevices, caves, tree crevices, bridges	M
Northern Myotis *Myotis septentrionalis*	S3S4 – Blue/ Endangered	Sometimes	Caves, tree crevices, bridges	N
Little Brown Myotis *Myotis lucifugus*	S4 – Yellow/ Endangered	Sometimes	Rock crevices, cliffs, caves, tree crevices, bridges	M/N/D
Fringed Myotis *Myotis thysanodes*	S3 – Blue/ Special Concern	Sometimes	Caves, cliffs, rock crevices, tree crevices, bridges	M/N/D
Long-legged Myotis *Myotis volans*	S4S5 – Yellow	Sometimes	Cliffs, rock crevices, caves, tree crevices, bridges	M
Yuma Myotis *Myotis yumanensis*	S5 – Yellow	Frequently	Rock crevices, caves, tree crevices, bridges	M
Canyon Bat *Parastrellus hesperus*	Accidental	Rarely	Rock crevices, cliffs	D
Mexican Free-tailed Bat *Tadarida brasiliensis*	Accidental	Frequently	Rock crevices, cliffs, caves, bridges	M/N/D

[a] Federal listings, where applicable, are under the *Species at Risk Act*. Status listings are current as of November 2021.
[b] See Chapter 1, Table 5 for a full summary of types of roosts used by bats in British Columbia.

Bridge crevices provide highly valuable roosts because of their permanence and stable microclimates, whereas roosts in decaying trees or under loose bark are more abundant but ephemeral. Bats tend to use more permanent roosts repeatedly over many years and may show stronger site fidelity than bats that use ephemeral roosts, such as tree bark (Lewis 1995). If a bridge roost is destroyed or made ineffective (e.g., the roost entrance is obstructed, the interior environment is modified, or the roost site is disturbed), an alternative equivalent roost site may not be available.

The types of features on bridges that may be used by bats are diverse and include deep, narrow crevices (generally 1.9–2.5 cm wide and at least 30 cm deep) that are part of a bridge's structure and are perfect for crevice-dwelling bats (Keeley and Tuttle 1999) (Figure 1). For example, bats may use:

- crevices and corners formed by expansion joints;
- concrete box beams;
- gaps between stringers, hinge joints, and abutment crevices;
- crevices formed where new bridge pieces are added to old bridge structures;
- drainpipes;
- narrow spaces where bridge structures interface with a rock face; and
- spaces behind signage attached to bridges (Erickson et al. 2002; US DOT 2015).

Bats also roost in abandoned Cliff Swallow (*Petrochelidon pyrrhonota*) and Barn Swallow (*Hirundo rustica*) nests on large culverts or other structures (Keely and Tuttle 1999), but it is not known how widespread use of these features as roosts is in British Columbia.

Bats use wooden trestle and steel bridges but may favour concrete bridges for roosting because of the microclimates and crevices they provide. Concrete structures or bridges located in warm sites can provide a thermal mass that retains daytime heat into the night (Erickson et al. 2002).

Figure 1. A wooden bridge used by a maternity colony of Myotis bats (left), and the underside showing crevices used for roosting (right). Photos courtesy of O. Dyer.

Use of bridges likely changes seasonally. In British Columbia, bridges are most likely used as night roosts, as day roosts by males and non-reproductive females, and as maternity roosts (a day roost composed of reproductive females and their young). Bats in British Columbia are unlikely to use bridges as hibernation sites; however, in some parts of the province, wintering bats may use rock crevices (i.e., deep crevices with stable cold temperatures) associated with bridge structures that have suitable features.

Roost temperature requirements vary depending on the type of roost. Maternity roosts are typically warm or even hot; they are important for young, non-volant (not yet flying) bats who remain in the roost while their mothers forage. Day roosts used by non-reproductive females and males tend to be cooler but warm up in the late afternoon. Night roosts are usually warm, open, and protected from wind.

1.4.1 Maternity roosts

Maternity roosts are used in spring and summer by pregnant or nursing adult female bats. Large numbers of bats in a day roost (Figure 2) typically indicate the presence of a maternity roost; visual observation of adult bats with young can confirm that the site is a maternity roost. Capture and examination of bats may be necessary to determine if the group is composed primarily of reproductively active adult females.

Reproductive females choose protected sites that are very warm throughout the day and night. Maternity roosts in bridges tend to receive full sunlight during most the day, have watertight seals, and are made of concrete (likely because it is very good at holding heat overnight) (Keeley and Tuttle 1999; Erickson et al. 2002; Smith and Stevenson 2015). Wooden bridges may also be used but seem to be less preferred (Keeley and Tuttle 1999). Flat-slab bridges with little structure underneath and metal bridges seem to be the least likely to be used by bats (Keely and Tuttle 1999).

Reproductive females choose roost locations that are protected from wind and predators (by finding crevices and crannies that are sometimes out of direct sight), and are positioned over vegetation or water; they tend to avoid bridges over busy roadways (Keely and Tuttle 1999).

Signs of a maternity roost in a bridge include:

- large groups of bats present during daylight hours;
- mothers with young bats visible;
- females visibly pregnant or showing signs of lactation (on close inspection by an experienced bat specialist with a provincial permit to handle bats);
- the presence of young, flightless bats that remain in the roost during the night;
- a concentrated pile of guano (i.e., feces); and
- mothers and young present at night on evenings that provide poor hunting conditions (i.e., cold, raining, high winds).

It can be very difficult to differentiate between a maternity roost and a day roost.

Figure 2. Day-roosting bats in a crevice of a bridge; no young bats are visible. Further investigation by a bat specialist would be required to determine if this is a maternity roost. Photo courtesy of I. Routley.

1.4.2 Day roosts (not maternity roosts)

A maternity roost is a type of day roost; however, non-reproductive females, males, and, later in the season, yearlings use day roosts that have quite different microclimatic characteristics than roosts that are used by reproductive females. Day roosts are characteristically used in

spring/summer and fall, and mixed groups of males, yearlings, and non-reproductive females can use or share the roost.

While reproductive females use warm roost sites, non-reproductive females, males, and yearlings use cooler roost sites, where they may go into torpor (a short-term [daily] state of inactivity achieved by lowering the body temperature and reducing the metabolic rate to save energy) (Nagorsen and Brigham 1993).

Figure 3. A large accumulation of fresh guano may be indicative of a maternity or day roost. Photo courtesy of O. Dyer.

Signs of a day roost of males or non-reproductive females in a bridge include:

- bats using the site during the day;
- a concentrated pile of guano (Figure 3);
- numbers of roosting bats that are typically fewer that those seen in a maternity roost (i.e., one or two, but possibly a small group of 8–12);
- the absence of non-volant young-of-year (age class can be determined by an experienced bat specialist who will examine the finger bones of the wing); and
- the presence of male bats.

On very cold, rainy, or windy nights, bats may remain in their day roosts because this type of weather is poor for hunting insects. It can be very difficult to differentiate between a maternity roost and a day roost.

1.4.3 Night roosts

Night roosts are sites where bats rest between foraging bouts during the night; bats may roost singly or congregate in single- or multi-species groups (Barclay 1982; Adam and Hayes 2000).

Night roost sites are often protected from the wind and provide a warm place where bats can digest their insect meal, defecate, and then head out for another bout of insect hunting before returning to their day roost. Huddling together in a group in this type of roost helps the bats keep warm, which conserves energy and increases the rate of digestion (Barclay 1982; Perlmeter 1996).

Night roosts are used only at night. The presence of bats at a roost during the night could indicate the location of either a night roost or a maternity roost because during summer, young bats that do not yet fly will be left at a roost during the night. On cold nights or nights with rain or high wind, non-reproductive females and males may also remain in their day roosts at night. Visiting a possible night roost during the day will allow alternative possibilities to be assessed.

Signs of a night roost in a bridge include:

- small or large congregations of bats roosting at night but not during the day;
- the presence of multiple bat species;
- the presence of mixed groups of males and females;

- the presence of volant (capable of flight) young; and
- the presence of fresh guano below the roost site during the day, but no bats present (a thorough investigation may be required to determine this because bats can hide in inconspicuous spots).

1.5 Concerns about bridge structures, human health, and bat health

Concerns about bats and bridges generally centre on the effects of guano deposition on the bridge, and effects on the health of personnel working in/around bats and bridges. Bats generally pose little risk to human health, but there are three related concerns: guano and urine, rabies, and histoplasmosis. Bats in British Columbia are not able to transmit the SARS CoV-2 coronavirus, which is responsible for COVID-19 (Bat Conservation International 2021). Additionally, there are emerging issues, primarily white-nose syndrome, that can affect the health of bats.

1.5.1 Bridge structures

Bat guano does not have a negative effect on the structural integrity of concrete bridges. The Congress Avenue Bridge in Austin, Texas, which is maintained by the Texas Department of Transportation, is a large concrete bridge over the Colorado River that has been used as a late-summer roost by up to 1.5 million Mexican Free-tailed Bats (*Tadarida brasiliensis*) annually for more than 30 years. The bats eat up to 4500–9000 kg (10,000–20,000 lb) of insects each night (BCI 2017). A long-term highway engineering study on the effects of large amounts of bat guano on the Congress Avenue Bridge structure revealed no negative effects on its structural components (Garrett 1996; Texas Department of Transportation 2021). Information is lacking on possible impacts to wooden or steel structures.

Figure 4. Staining from urine from bats roosting on the underside of a concrete bridge. Photo courtesy of M. Sarell.

1.5.2 Human health

1.5.2.1 Guano and urine

Bat guano and urine that accumulates on bridge structures (and in buildings) does not pose a significant risk to human health (Figure 4) (Craig et al. 2014; CDC 2020aa; Tuttle 2017). It is important, though, to distinguish bat guano from mouse or rat feces, which can be a source of hantavirus and therefore a serious human health concern (HealthLinkBC 2021). Bat guano and mouse/rat droppings are both about the size of a grain of rice and are dark coloured. However, unlike mouse/rat droppings, bat guano can be easily crushed into a powder that sometimes looks “sparkly” due to the small, undigested insect parts it contains. Mouse/rat droppings are hard and clay-like. As a precaution, always use a filter

mask when cleaning up bat guano, and if mouse/rat droppings are thought to be present, follow the suggested provincial protocols for preventing exposure to hantavirus (B.C. MOE 2017).

1.5.2.2 Rabies

Rabies is lethal to humans; post-exposure vaccinations must be obtained prior to the development of symptoms or as quickly as possible post exposure (B.C. CDC 2021). The rabies virus affects the central nervous system and causes disease of the brain, which leads to death (CDC 2020b). Like all mammals, bats can contract rabies, which can then be passed on to humans through a bite or the transfer of infected bodily fluids through an open wound or mucous membranes (B.C. CDC 2021). A person cannot contract rabies from bat guano or urine, or from a bat that flies past them. Simply avoiding contact with bats or wearing gloves when picking up dead bats will prevent exposure to the rabies virus (B.C. CDC 2021; Community Bat Programs of BC 2021).

Rabies occurs in less than 0.5% in the free-flying population of bats in North America (Community Bat Programs of BC 2021; Tuttle 2017). Bats on the ground, bats that are easily approached, and bats that exhibit abnormal behaviour have a higher probability of being sick than do free-flying bats; they need to be treated with caution. However, bats seen during the day or bats behaving "abnormally" do not necessarily have rabies. For example, in late July and August, young bats may end up on the ground during flight practice, or in houses due to losing their way. Bats may also be seen during the day in summer as they fly to get a drink of water during hot periods. Bats may also end up inside buildings just prior to hibernation (Tuttle 2017). Even though the incidence of rabies in bats is low, always take precautions by not handling bats (or any wildlife) bare-handed.

Anyone who has had direct contact with a bat must consult a doctor without delay. Immediately washing the site of contact with soap and water is also recommended. More information on rabies in British Columbia is provided on the B.C. CDC's (2021) rabies webpage (www.bccdc.ca/health-info/diseases-conditions/rabies) and in the British Columbia government's fact sheet on rabies (http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlifeediseases/rabies).

1.5.2.3 Histoplasmosis

Histoplasmosis is an infection caused by the spores of the fungus *Histoplasma* (CDC 2020a). The fungus can live in any soil that has high concentrations of bat or bird guano, but it thrives only in areas with high humidity; it is less prevalent in more arid climates. Infections arise when people inhale the spores of the fungus (it can cause fever, cough, and fatigue). Most people who are exposed to the fungus recover on their own without medication (CDC 2021b). However, for immune-suppressed individuals, or people with other health issues, histoplasmosis can be severe. To date, locally acquired histoplasmosis has not been documented in animals or humans in British Columbia (Community Bat Programs of BC 2021).

1.5.3 Bat health

In 2006, U.S. researchers reported an outbreak of an unidentified disease that has since killed millions of hibernating bats in mines and caves (USDA Forest Service 2012). The disease does not affect humans or other wildlife. The researchers called the infection white-nose syndrome, after the white nose characteristic of infected bats. The disease is caused by the fungus *Pseudogymnoascus* (prev. *Geomyces*) *destructans* (Gargas et al. 2009; Minnis and Lindner

2013). Bats develop the fungus on their nose and on their wing and tail membranes. White-nose syndrome is now recognized as a significant wildlife crisis in the United States and Canada, which threatens to cause the extirpation and/or extinction of a number of hibernating bat species (Blehert et al. 2009).

The disease was first discovered in Canada during the winter of 2009–2010, in Ontario (Ontario MHLC 2013) and Quebec (Quebec MNRF 2010). In response to mass mortalities of three bat species in eastern Canada, the Committee on the Status of Endangered Wildlife in Canada conducted emergency assessments of Little Brown Myotis and Northern Myotis, both of which occur in British Columbia, and Tri-colored bat (*Perimyotis subflavus*), an eastern species; all three species were assessed as Endangered (COSEWIC 2012). The federal environment minister accepted this listing for the inclusion of these species on Schedule 1 of the *Species at Risk Act* on December 17, 2014 (Environment Canada 2014). In March 2016, about 200 km south of the British Columbia border, wildlife officials recorded an infected Myotis bat in King County, Washington; the disease continues to spread and infect western bat species (WDFW 2021). However, to date, white-nose syndrome is not known to occur in British Columbia.

Recovery strategies have been produced for the three federally endangered bat species, including the two species found in British Columbia: Little Brown Myotis and Northern Myotis (Environment and Climate Change Canada 2018). Surviving individuals in post-white-nose syndrome populations (i.e., areas where the disease has already been recorded and bat losses have occurred) are key to rebuilding populations. It is not yet known which characteristics allow some bats to survive—it could be genetic, behavioural, or a combination thereof—but in any case, surviving individuals require even higher levels of protection and support to ensure that species are not extirpated and populations can increase.

People moving between sites that are used by bats may unknowingly spread the fungus that causes white-nose syndrome. Fungal spores can also be transported via human clothing and mud on boots or equipment. Recent research has indicated that spores of the fungus can remain viable throughout the summer and may be present at summer roosts. Fungal spread may be possible from contact with guano or bats. Decontamination procedures need to be followed at both winter and summer bat roosts to minimize human transport of fungal spores between roosts.

More information on white-nose syndrome is provided in Chapter 1 and on the B.C. Wildlife Health website (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-diseases/white-nose-syndrome-wns). Decontamination procedures are listed on the Canadian Wildlife Health Cooperative website (www.cwhc-rcsf.ca/wns_resources.php). Research on this issue is ongoing; therefore, consult the latest decontamination procedures available.

Research updates and disease spread maps are provided on the U.S. Fish and Wildlife Service White-nose Syndrome Response Team website (https://www.whitenosesyndrome.org/about-white-nose-syndrome).

2 Bridge management and potential impacts on bats and their roosts

Bridge management activities can directly or indirectly affect bats that use bridges as roosting habitat. Repair and maintenance , removal or major structural alteration, new bridge construction or bridge replacement, and lighting can all have impacts on bats and their habitats. Impacts can include direct mortality, disturbance, and/or habitat loss or alteration.

Direct mortality of individual roosting bats can be cause by frequent, small-scale activities, including bridge maintenance, repair, inspection, and power washing, Large-scale works such as bridge removal, alteration, or replacement can also result in direct mortality of bats, particularly if these activities occur when non-flying young are present.

Some bridge maintenance, repair, inspection, and power washing activities may cause a short-term or temporary disturbance of bats (i.e., hours or less than a day or two), but repeated disturbance at roost sites and/or during a critical time in a bat's life cycle can cause roost abandonment and the use of suboptimal roost sites, which ultimately can result in population declines (US DOT 2015).

Habitat loss or alteration may occur due to bridge construction, removal, alteration, or replacement, and can be a permanent change that may impact roosting bats. Bridge removal or alteration that makes a roost site unusable can negatively affect bats if no alternative roost habitat is available within the bats' average foraging distance from the roost site. Even small-scale bridge modification can degrade roosts, especially if the activity occurs while bats are occupying the site.

Land management activities (timber clearing, road building, construction) in the area surrounding a bridge that is used by bats can degrade or improve the quality of the site for bats. The habitat that surrounds a roost can influence the roost's accessibility and microclimate which can have positive or negative impacts; it can also affect predation risk for bats that use the site (Kalcounis and Brigham 1998; Jung et al. 1999). Wetlands, ponds, and riparian habitats provide important foraging and drinking habitats for bats. Construction of any kind that affects waterways and the adjacent terrestrial habitat that bats use (rock features, older tree stands, or wetlands and riparian areas) should be assessed to avoid or mitigate possible impacts.

Land management activities may also involve alteration or removal of rocky habitats. Chapter 3: "Best Management Practices Guidelines for Caving, Rock Climbing, Geocaching, and Other Activities around Cave and Crevice Habitat" provides information on the potential impacts of these activities on bat populations in British Columbia, and includes Best Management Practices for mitigating the impacts of new construction projects located near karst or other rock features that bats use.

2.1 Bridge repair and maintenance

Bridge repair and maintenance occur throughout the lifespan of a bridge and provide many opportunities to assess bat presence, but they can also impact bats.

Bridge repair and maintenance activities include cleaning (power washing), preventative maintenance to preserve and lengthen the operational life of the bridge, technical and specialized repairs of bridge infrastructure, and maintenance of features below the bridge (e.g., stream channel, roadway, railway). These activities may involve the use of support vehicles, pavement repair, and welding and grinding operations, and the application of chemicals.

Repair and maintenance activities can result in disturbance or direct mortality of bats, and impacts on bat health. Activities that produce noise, vibration, or increased light, or that reconfigure large parts of a bridge or parts of the surrounding topography may directly disturb roosting bats. Disturbances may disrupt foraging times or cause bats to take flight and leave the roost during the day, drop pups, or become agitated during roosting (Smith and Stevenson 2015; US DOT 2015). Activities that produce dust and noise can also affect nearby bat colonies (Smith and Stevenson 2015). Bridge repair and maintenance activities around the roost may change the roost's attributes, especially humidity, temperature, or the flight approach to the roost, which could force the bats to change the way they enter or exit the roost. Although these activities may be temporary, they can lead to the abandonment of a maternity roost, which would be considered a significant impact in most cases (Johnston et al. 2004).

Bridge repair and maintenance activities may not have adverse effects on bats and their roost sites if the work does not directly affect the bats or their roost area and does not create excessive disturbance in the form of noise, light, or vibration. Normal cleaning and maintenance activities are not likely to disturb roosting bats, provided they do not directly affect the roost sites or the bats themselves (US DOT 2015).

Bridge repair and maintenance is NOT likely to have adverse effects on bats when it occurs:

- outside the active season (the period when bats are using the bridge or surrounding habitat for roosting),
- within the active season but
  - does not directly impact bats, and/or
  - does not require adjusted lighting regimes, and/or
  - does not alter bat roosting habitat (US DOT 2015).

Examples of maintenance activities during the bats' active season that are not likely to significantly affect roosting bats include road paving; wing-wall work; some abutment, beam end, scour, or pier repairs; and work on the bridge deck that does not drill down into the underside of the deck (US DOT 2015). Tree removal that occurs outside the bats' active season and does not remove documented roosts will also likely have no effect on bats, especially if BMPs for maintaining water quality are implemented (US DOT 2015).

2.2 Bridge removal or alteration

Permanently removing or altering bridges that are occupied by bats may have a direct, negative impact on the bats. Alteration is defined as maintenance or construction activities that permanently modify roost areas on a bridge (US DOT 2015). Work may cause disturbance or direct mortality if it is conducted when bats are present. Even if bats are not present when the work is done, the habitat loss from removing or permanently altering a bridge that has been used as a roost site in the past may have a negative effect on the local bat population, especially if there is a lack of alternative roosting habitat near the site. This is especially true for colonies that have used the same bridge as a maternity roost site for many years. Bridge removal or alteration may cause colonies to disperse, which may impact foraging and pup-

rearing behaviours or cause females to become energetically stressed as they search for alternative sites that provide suitable maternity roosts (US DOT 2015). Bridge removal or alteration may also force large colonies to break up into smaller colonies and could impact reproductive success of the colony.

If bridge alteration can be completed when bats do not occupy the site, and the roost site is not altered or rendered inaccessible, there will likely be no impact on roosting bats.

2.3 Bridge construction

New bridge construction or bridge replacement may involve activities that affect roosting bats and their habitats in the surrounding area. Clearing of trees, blasting and removal of rock features, and disturbance of riparian and wetland areas can affect potential roosting and foraging habitat for bats (US DOT 2015). Clearing and grading for road widening, clearing and grubbing of streamside vegetation, construction of storm water facilities, excavation for new bridge abutments, construction of bridge columns/piers/abutments, concrete pouring, pile installation and removal, bridge demolition, riprap replacement, and paving with asphalt or concrete may be involved in the construction of new bridges or the replacement of existing bridges (US DOT 2015). Bats in natural roosts (especially in rock features) that are located within or near the construction site may be disturbed by the light, noise, or dust that is generated by construction activities, or by direct contact with construction activities. Chapter 3: “Best Management Practices Guidelines for Caving, Rock Climbing, Geocaching, and Other Activities around Cave and Crevice Habitat” provides guidance on identifying bat roosting habitats in rock and other natural crevices, and includes associated Best Management Practices.

2.4 Lighting

Artificial lighting can affect bats directly and indirectly in several ways. For example, light can delay or prevent bats from emerging at dusk or cause them to abandon their roost site. For detailed information on how artificial lighting affects bats, and how these impacts can be reduced, refer to the background document “Artificial Lighting and Bats” available with the Best Management Practices guidelines (http://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12460).

3 Best Management Practices guidelines

Bridge repair and maintenance, removal or alteration, and construction offer multiple opportunities to consider bats and bat habitat and implement Best Management Practices for bat conservation (Table 2). This section provides general guidance but does not replace the need for an experienced bat biologist to develop a detailed site-specific plan.

Table 2. Recommended process for addressing bat use of bridges

Assessment	Define the assessment area in terms of (a) the local area of impact, and (b) a regional area of impact in which to assess ecosystem/population-level effects. Gather existing data about potential bat occurrence and bat habitat for the local and regional areas. Determine if bats are using the site; note the species present and estimate their relative abundance, if possible. Assess the presence, use, and regional importance of specific bat habitats.
Planning	Based on the assessment and existing data, assess the level of risk posed by the bridge management activity and determine whether specific bat management plans are necessary. If management plans for bats are required, develop a "Protection Plan" following the steps in the *Environmental Mitigation Policy and Associated Procedures*: avoid, minimize, restore, offset (B.C. MOE 2014a). Offsetting may involve compensation or trade-offs with conservation benefits outside the development area.
Avoid/ minimize	Avoid displacement or mortality of bats by timing activities when bats are not occupying roosts (temporal separation). Avoid destruction/degradation of bat roosts by avoiding alteration of those features (spatial separation). Avoid adverse impacts on bats by modifying the techniques used for bridge management. Minimize the use, timing, or duration of activities that impact bats.
Restore	Ensure bat roost sites impacted by bridge work are restored to pre-work conditions.
Offset: mitigation and compensation	Use habitat enhancement (e.g., erection of bat boxes or artificial concrete "caves", creation of ponds and wetlands) within the development area to immediately replace roosting and foraging features that are affected by the development. Plan for future recovery of bats that are adversely impacted by the development by establishing wildlife tree reserves and green tree recruitment, or use snag creation techniques to provide future roosting opportunities. Consider implementing compensatory protection of equivalent habitat within the regional area surrounding the development area, with a goal of "no-net-loss" of habitat at the regional level or within the bat populations' range. Ensure the appropriate level of offsetting is employed.

Bats are dependent on wetlands, rivers, riparian areas, and ponds for drinking and foraging habitat. It is important to follow recommended pollution prevention measures to control storm water discharge (which may include litter, construction chemicals, and debris) and minimize impacts on water quality from erosion, sedimentation, or spills (US DOT 2015). British Columbia has guidelines for construction near wetlands and waterways, and for the construction of water-crossings (http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/working-around-water).

British Columbia has also produced "Develop with Care" guidelines (B.C. MOE 2014a) for maintaining environmental values during urban and rural land development (https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/best-management-practices/develop-with-care). The guidelines are intended to be used by local governments, the development community, landowners, and environmental organizations, and they include an "Environmentally Valuable Resources" section that provides information on aquatic and riparian ecosystems, and guidance on appropriate buffers, protection, and restoration for various species and habitats.

Mitigation is defined as the measures implemented to control, reduce, or eliminate potential adverse impacts of a project, and includes restorative measures and compensation for a loss (EAO 2003). Additional information on the province's Environmental Mitigation Policy are available on the Ministry's website (https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/environmental-guidance-and-policy/environmental-mitigation-policy).

3.1 Determining use of bridges by bats

When conducting bridge repair, maintenance, alteration, or removal, it is important to determine if and how bats use the bridge in question.

To assess bat presence at a bridge, follow the basic survey methods presented below and in Appendix 1, and see Appendix 2 for advanced bat surveys. Surveys should encompass a variety of weather conditions and seasons, depending on the specific objective of the survey. The basic survey methods could be incorporated into regular bridge maintenance work. Basic information for each bridge can help managers determine if bat conservation work is needed at the site; information of any kind is valuable.

- Inspect all bridge types for bats (see Sections 3.1.1 and 3.1.2). A quick initial assessment can often determine if bats are occupying bridge structures at the time of inspection; however, repeated inspections at different times of the day and in different seasons are recommended. If bat use is suspected but not confirmed, further investigation of the site should be conducted by an experienced bat specialist.
- Structures where bats have been determined to be "not present" do not require avoidance measures. If bats are found at the site after work has started, Best Management Practices should be implemented.
- If a roost site is being used or has been previously used by bats, a site-specific assessment should be conducted to determine when and how work can safely proceed and if the bridge work will eliminate or degrade the roost site.
- Track the results of any bat surveys to help determine when and where assessments of bat habitat, presence, and use are essential in the future, or where the need for assessment prior to the commencement of work might be minimal.

3.1.1 Protocols for basic bat surveys at bridges

A basic survey involves a brief examination of bridge structures for the presence of bat sign and any indications of the type of roost that is being used (Figure 5). This type of survey can be completed by bridge personnel as part of regular bridge inspection work. The basic survey is short and informative. Data can be recorded on a datasheet such as the example in Appendix 1.

Transfer all information from the datasheet into the bat data template available from SPI_Mail@gov.bc.ca, and submit it to the B.C. Wildlife Species Inventory database (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information).

Alternatively, submit bridge survey datasheets to the B.C. Ministry of Environment and Climate Change Strategy's (ENV) Small Mammal Specialist or Bat Conservation Coordinator. It is important to submit records of bridges without bats as well as those with bats.

3.1.1.1 Survey and bridge information

At a minimum, record:

- date and time of the survey
- surveyor names
- location of the bridge/site description
- bridge ID: Ministry of Transportation and Infrastructure IDs of the various bridges and structures can be obtained from https://catalogue.data.gov.bc.ca/dataset/ministry-of-transportation-mot-road-structures
- proposed bridge management activity
- general bridge description:
  - bridge type: construction type, materials used for abutment, underdeck, beams, columns
  - purpose of bridge: bridge use (e.g., vehicle, train, pedestrian), crossing type
  - bridge height (at its centre)
- habitat around the bridge

Take and label photographs of bridges, potential roost sites, and surrounding habitat.

Figure 5. Expansion joints in a concrete bridge can provide roosting habitat (left). Staining around a joint may indicate use by bats (right). Photos courtesy of O. Dyer.

3.1.1.2 Bat information

- Inspect existing infrastructure for potential roost sites:
  - Identify structural fissures (cracked or spalled concrete, damaged or split beams, split or damaged timber railings, other visible cracks).
  - Identify crevices (expansion joints, space between parallel beams, spaces above support piers, other crevices visible).
- Inspect alternative structures (drainage pipes, bolt cavities, open sections between support beams, swallow nests, other structures) for potential roost sites.

- LOOK and LISTEN for bat sign and activity at each potential roost site, and note its location.
- Evidence of use by bats could include:
  - presence of live or dead bats;
  - presence of pups (at a maternity roost);
  - urine staining (Figures 4, 5),
  - guano (Figures 6, 7);
  - moth wings or insect parts;
  - body oil staining on concrete; or
  - high-pitched squeaking sounds.
- Estimate the amount of guano and where it is distributed (dispersed: likely night roost; clumped: likely day roost).
- Collect a guano sample (Section 3.1.2).
- Assess the type of roost (day/night/maternity roost likely or unlikely):
  - night roost: guano stuck to surfaces, no obvious crevices, no bats present during the day; droppings or urine stains without the obvious presence of bats during the day,
  - day roost: usually in cracks or crevices; bats may be seen roosting during the day,
  - maternity roost: a day roost with reproductive females and their pups (Figure 8); often large guano accumulation
- Conduct a bat emergence count: visual counts at bridge roosts during bat emergence (when bats exit around sunset to forage) are useful for determining colony size. If completed, fill out and submit a BC Annual Bat Count form (https://bcbats.ca/get-involved/counting-bats/).

Figure 6. Guano accumulation under a wooden bridge, Okanagan. The clumped distribution of guano suggests a maternity/day roost. Photo courtesy of O. Dyer.

Figure 7. Bat guano is similar in size and shape to mouse droppings but crumbles easily into insect parts. A small sample of bat guano can be collected and used to identify bat species at a bridge roost. Photo courtesy of Community Bat Programs of BC.

Figure 8. A maternity roost is confirmed by presence of young bats; note differing sizes and colours of bats in this bridge roost. Photo courtesy of M. Sarrell.

- Note the presence of swallows and/or swallow nests (Figure 9). Nests, abandoned or occupied, can provide roost habitat for bats. Bats that use Barn Swallow nests may lie flat within the nest cup; bats that use Cliff Swallow nests (which are gourd-shaped, enclosed structures made of mud) are typically concealed and undetectable without the use of a borescope or fiberscope.
- Take and label photographs of potential and confirmed roost sites and evidence of bat use.
- RECORD your findings on a datasheet, such the example in Appendix 1.
- Make sure you record bridges with NO roost sites and NO sign as well as bridges with potential or confirmed roosts.

Figure 9. Mud nests of Cliff Swallows under a bridge. Bats can roost inside these gourd-shaped nests. Photo courtesy of T. Chatwin

3.1.2 Guano sampling for species identification

A sample of bat guano can potentially be used to identify the species of bat using a bridge or to test for the presence of the fungus responsible for white-nose syndrome in bats (Figure 10). Collect samples following the directions below, then submit them to ENV's Small Mammal Specialist or to Community Bat Programs of BC (www.bcbats.ca). Not all samples will be analyzed.

Required equipment:

- Disposable gloves (e.g., latex gloves that can be purchased at a pharmacy) or clean tweezers
- Small paper envelope (such as a coin envelope, or cut a large one into a smaller size and seal with tape)
- Cotton balls
- Pen or pencil

Figure 10. Collect a few guano pellets in a paper envelope to identify the species of bat present at a roost. Photo courtesy of Community Bat Programs of BC.

Guano collection protocol:

- Never touch a living or dead bat with your bare hands.
- Do not handle or disturb roosting bats.
- Select guano from the current year that is dry (if there is a pile, this will be the guano on top of the pile versus near or at the bottom) and has had minimal exposure to sun and water.
- Avoid touching guano directly.
- Wear gloves, use tweezers, or scoop guano into a coin envelope.
- Use a cotton ball for padding to prevent crushing.
- Clean tweezers or change gloves between locations if you are collecting from multiple locations.
- At least 2–3 pellets are required for single-species ID; up to 200 pellets (1 Tbsp/30 mL) are required for multi-species testing using DNA barcoding.
- If there are multiple roost sites or a building with hundreds of bats, use a separate envelope for each location (e.g., one envelope per bat house, one envelope for each cluster of bats, or one envelope for each end of an attic).
- Do not put samples in a plastic bag: they need air flow.
- If the samples cannot be mailed within 14 days, dry them thoroughly and keep them out of direct light.
- Label envelopes/vials with the:
  - collector's name and contact information;
  - date the guano was collected;
  - location description (e.g., "north side of bridge"); and
  - address and GPS coordinates of the roost (if possible).

Note: Bat guano rarely poses a human health risk in British Columbia. However, wear a mask to avoid inhalation of dust particles in areas where bats or other wildlife have defecated, especially within confined areas such as attics.

3.2 Working around a confirmed roost

- NEVER poison, pressure wash, trap, relocate, or in any other manner harm, harass, or kill bats. These techniques are not only ineffective in deterring bats from using bridge structures, they are also illegal under the British Columbia *Wildlife Act* and do not comply with minimum acceptable standards. Ensure that all workers are aware that they must comply with the *Wildlife Act*.
- Follow timing windows (Table 3) to avoid working when bats are occupying a roost. This is the best strategy, particularly for maternity roosts. Consult a regional biologist to obtain specific dates.
- If timing windows cannot be respected and bridge work must be performed during the period when bats may be present, a bat specialist should be consulted to establish a bat management plan based on the type of roost and site-specific details. For example,
  - for maternity/day roosts:
    - aim to restrict activities to late season (1 September, onward) after the roost has been vacated (young have fledged);
    - avoid bridge activities during June and July (when non-volant pups are present);
    - if work must occur at an occupied roost from April to May (before pups are born) and August to September (after pups have fledged), use appropriate exclusion

techniques and keep work areas lit (but localized) to discourage bat use during the work period; and
        - once pups are flying (usually within 3-6 weeks of birth), maternity colonies often move away from a roost site. If a maternity colony site is verified as vacant in late summer and work is to occur in late summer/fall, exclusion methods should be used to ensure that bats do not opportunistically return to the site.
    - Consider conducting bridge work while bats are away from the roost—e.g., only during the day for night roosts; however, effective exclusion must be applied if there is a risk of mortality to roosting bats from bridge work.
    - Retain features used by bats and ensure the roost remains suitable for them after work has been completed.
    - Consider off-site compensation or on-site habitat enhancement.
- Before commencing work, conduct a pre-work survey for bats at the bridge within 7 days of starting the planned work to ensure that bats have not taken up residence since the initial inspection (US DOT 2015).

3.2.1 Encountering live bats (day or night)

- Leave live bats alone if it is safe to do so (e.g., they are out of the way and no bridge work is occurring). Take a photograph and report the bats and location *(see Section 4: Reporting).
- If the bats are not in a safe spot (e.g., they may come in contact with a human, or bridge work is occurring) contact ENV's Bat Conservation Coordinator or Small Mammal Specialist.
- Never touch a bat with your bare hands. Anybody who has had direct contact with a bat must consult a doctor without delay. Immediately washing the site of contact with soap and water is also recommended. More information on rabies in British Columbia is provided on the B.C. CDC's (2021) rabies webpage (www.bccdc.ca/health-info/diseases-conditions/rabies) and in the B.C. government's fact sheet on rabies (http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-diseases/rabies).

3.2.2 Encountering dead bats

- Report all dead bats to the Wildlife Health Program (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/bats#foundabat) and/or www.bcbats.ca. Send a photograph and location information. See Section 4: Reporting.
- Dead bats found from 1 November to 31 May should be collected so the B.C. Wildlife Health Program can test them for white-nose syndrome. In the spring, bats returning from hibernation may die from being exposed to this disease during winter. Note that white-nose syndrome does not affect humans.
    - Put on gloves.
    - Put the bat in a plastic bag or container.
    - Add a label with the date, location, and your contact information.
    - Freeze the bat.
    - Contact www.bcbats.ca or ENV's Bat Conservation Coordinator or Small Mammal Specialist for more directions.

3.2.3 If you find a pile of bat guano

- A pile of guano can be a valuable find. If you suspect you have found bat guano, take a photograph and report the guano and location to www.bcbats.ca or contact ENV's Bat Conservation Coordinator or Small Mammal Specialist for further directions (see Section 4: Reporting).
- Bat guano in British Columbia does not pose any special health hazards. Histoplasmosis has not been detected in the province.
- However, because of dust and potential hantavirus in rodent droppings, always wear appropriate personal protective equipment if you must clean up guano deposits.

3.3 Avoiding/minimizing impacts on bats at bridges

A management plan for bats should be made if:

- there is suspicion or evidence that bats are roosting on/in the bridge;
- a permanent, occupied roost in a natural feature is present in the area; and/or
- other significant bat habitats (roosting or foraging habitats) are within the area of influence of the planned activities.

Prior to initiating any activities near bat roosts, proponents should identify the type of roost and the seasonal timing of use, the expected level of disturbance, and the planned schedule of activities as part of the bat management plan. The plan should include avoidance measures plus mitigation and compensation measures if impacts on bats may occur. If no bats are present at the bridge, the site should continue to be monitored in case bats start to use it in the future.

Human activities can be divided into three levels of disturbance: low, medium, and high impact (ABSRD 2011). The expected level of disturbance depends on activities that will occur. Bridge removal or alteration (e.g., increasing the size of the bridge deck) are large construction projects that result in either a permanent change to the roosting area (in the case of bridge removal) or a lengthy period of significant construction activity (in the case of bridge alteration); they are considered high-impact activities. Conversely, minor maintenance activities may have medium to low or no impact on bats.

There are two ways of avoiding impacts on bats and their habitats:

1. temporal avoidance (establishing timing windows for activities), and
2. spatial avoidance (creating appropriate buffers).

3.3.1 Timing windows

Because bats use different habitats in different seasons, impacts can be avoided by conducting work when bats are not present. The pattern of events in a bat's life cycle can be generalized (Figure 11); however, the exact timing of those events varies from region to region and should be determined in consultation with a bat specialist. Bridge management activities that may impact bats should be avoided during periods when bats are most sensitive.

In British Columbia, the most sensitive periods for bats are hibernation and the period following parturition, during which young are not yet able to fly. The timing of these periods varies slightly depending on the biogeoclimatic zone and seasonal variation in weather. Generally, October to March is the most sensitive period for hibernating bats, and May through August is the most sensitive period for bats that are raising pups until they are capable of flight. However, cool, wet springs are correlated with later birth periods, and early, warm springs can bring bats out of hibernation or initiate the reproductive period earlier than normal (Grindal et al. 1992; Holroyd 1993). The timing of emergence and birth can vary by 2–3 weeks between years in the same area, or in a given year, between areas with significantly different climatic conditions (Grindal et al. 1992; Holroyd 1993).

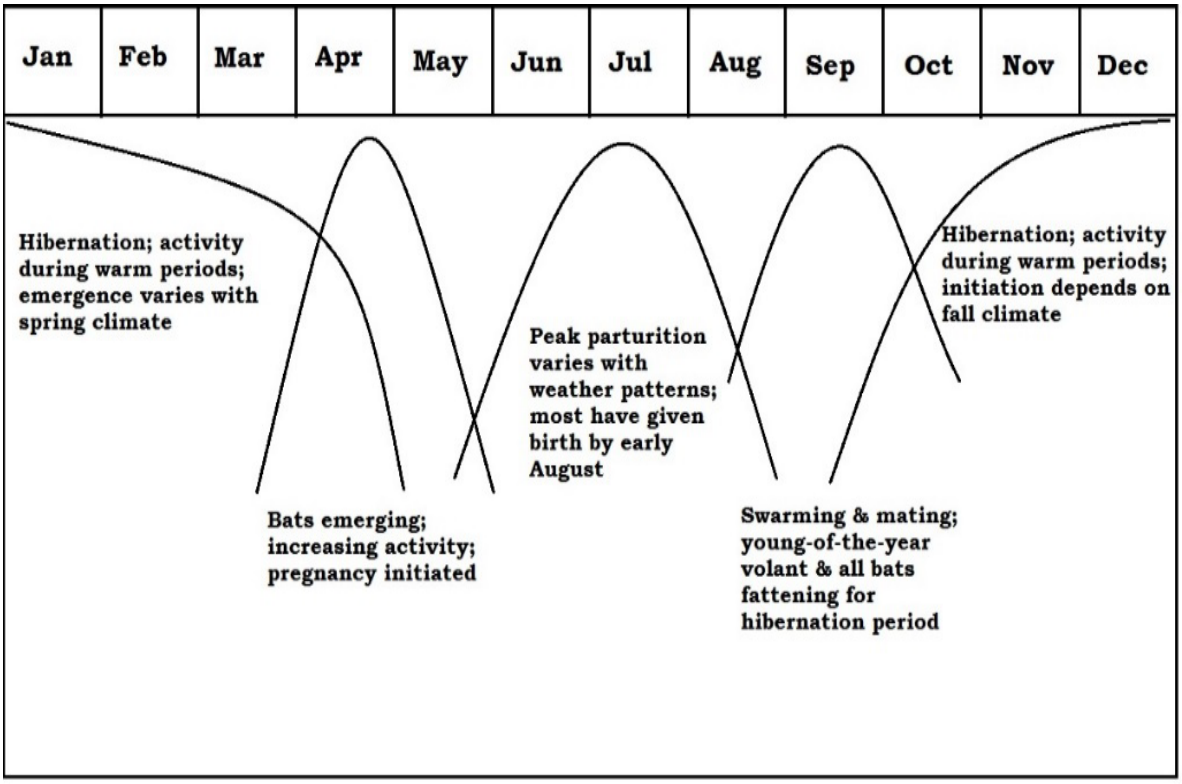

Figure 11. General seasonal patterns of bat activities in British Columbia. The Y-axis represents relative amount of bat activity. Figure courtesy of S. Holroyd.

The following general timing windows have been developed for bats in bridges:

- Maternity sites/day roosts: avoid activities between 1 May and 31 August.
- Night roosts: avoid activities AT NIGHT between 1 April and 31 October.
- Hibernation sites: avoid activities between 1 October and 31 March.

3.3.2 Buffers

Impacts on bats and their habitats can also be avoided or diminished by moving development activities away from bat habitats. Proponents who are establishing new bridges and/or undertaking bridge replacements may not have the same amount of siting flexibility as some other resource sectors, but they should consider the location of important “permanent type” roost features for bats (e.g., hibernation sites or summer roost sites in rock features) when establishing bridge alignments. On and around bridges that are used by bats, simple strategies can be used to demarcate roost sites, and setbacks can be used for construction infrastructure (e.g., location of gravel piles or bypass roads) to avoid disturbing bats.

Setback distances vary based on the degree to which bats or bat habitat will be affected by the proposed activities. Activities that involve the creation of permanent structures or are expected to have long-term effects (i.e., more than 10 years) on vegetation or hydrology require the largest setback distances; activities that have little or no effect on vegetation or hydrology have the smallest setback distances (ABSRD 2011).

Identify bat habitat and setback boundaries as follows:

- identify the extent of the roost. A roost area includes all possible entrances and exits (portals) and the full extent of suitable roosting habitat within a bridge structure;
- establish a 100-m radius “core area” around the roost area (in the example in Figure 12, the entire bridge is the roost area); and
- identify an additional 1-km radius “special management zone” around the “core area” (Figure 12).

By using a combination of timing windows and spatial avoidance as outlined in the BMPs in Table 3, it may be possible to work around bats at some sites if bridge management activities are not highly disruptive. In other instances, work will need to be rescheduled, or bats may have to be excluded from an area, at an appropriate time, in order to allow work to proceed.

The use of sealants on bridge cracks and crevices could entomb bats or cause abandonment of dependent young; therefore, it should be conducted based on the advice of an experienced bat biologist (Smith and Stevenson 2015).

For blasting and jackhammering, ensure that sound concussion is less than 150 dB, the shock wave is less than 15 PSI, and the peak particle velocity is less than 15 mm/sec (B.C. FLNRO 2014), or (for blasting) maintain a setback of 2 km from occupied roost sites, especially known hibernation sites (Delaney 2002). Blasting is permissible when bats are not occupying the roost; however, ensure that the roost habitat is not degraded in any way.

In general, maintenance or repair activities at bridges that have a known bat roost should be conducted based on the advice of an experienced bat biologist.

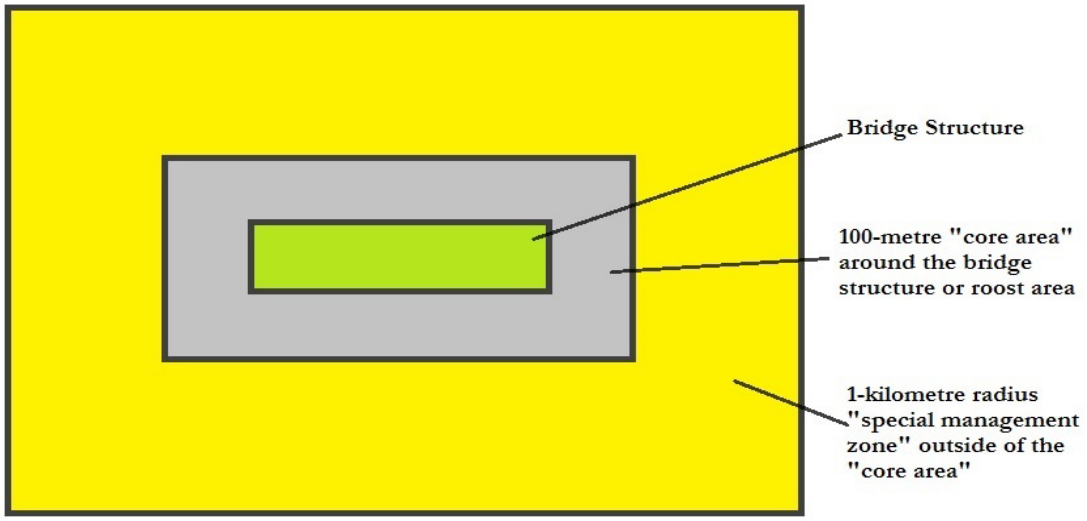

Figure 12. Establish a 100-m radius "core area" and a 1-km radius "special management zone" around identified roost complexes at bridges. The roost area should include the full extent of the suitable roosting habitat. Figure courtesy of S. Holroyd.

Table 3. Acceptable levels of disturbance to bats and their habitats due to human activities at bridges. This information can be used in planning acceptable activities within the core area (100-m buffer) and special management zone (additional 1-km buffer) around bat roosts (adapted from ABSRD 2011). Timing windows are as follows: maternity sites/day roosts—avoid activities between 1 May and 31 August; night roosts—avoid activities AT NIGHT between 1 April and 31 October; hibernation sites—avoid activities between 1 October and 31 March.

Level of disturbance	Examples of potential activities at bridge sites	Acceptability
Low-impact disturbances often occur infrequently, habitat is not being modified by the activities, and the duration of the activity is relatively short (i.e., hours).	Bridge inspections Wing-wall work	Acceptable immediately adjacent to a roost and in the 100-m core area during the occupied period if there will be no direct or indirect impacts on bats; use extra caution immediately adjacent to the roost Acceptable in the 1-km special management zone all year (low-impact activities are localized at the bridge site)
Medium-impact disturbances usually occur with high frequency, may involve the use of vehicles and other equipment, may involve small habitat modifications, and the duration is relatively long (i.e., days to months).	Minor bridge or abutment repair Paving Maintenance (power washing, painting, surface treatments; primarily when treatments affect the bridge underside where bats potentially roost)	Not acceptable immediately adjacent to a roost during the occupied period May be acceptable in the 100-m core area during the occupied period if there will be no direct or indirect impacts on bats or bat habitat (review by bat biologist). OR avoid impacts by following timing windows Acceptable in the 1-km special management zone all year (medium-impact activities are localized at the bridge site)
High-impact disturbances generally occur with high frequency, involve vehicles and machinery, permanently modify the habitat by altering vegetation, soils, geomorphology, and perhaps hydrology, and the impact is long term (i.e., years). ! Very high-impact activities such as blasting and jackhammering require a 2-km buffer (see text).	Construction (new bridge construction, bridge replacement, large-scale bridge repair, removals) Forest harvesting Use of heavy equipment Land clearing Excavation Road building Blasting Jackhammering	Not acceptable immediately adjacent to a roost or in the 100-m core area during the occupied period; follow timing windows May be acceptable in the 1-km special management zone during the occupied period if there will be no direct or indirect impacts on bats or bat habitat (review by bat biologist), OR avoid impacts by following timing windows See text re: blasting and jackhammering.

3.3.3 Exclusion

If impacts on bats cannot be avoided or reduced through temporal or spatial avoidance, the bats can be excluded from the work site temporarily or permanently prior to conducting the work.

- Any exclusion of bats must occur during appropriate timing windows (Section 3.3.1) and should always involve a bat specialist. Exclusion must not be conducted when pregnant females or young bats could be present (generally 1 May–31 August).
- Conduct a pre-work survey for bats at the bridge within 7 days of starting the work to ensure that bats have not taken up residence since the initial inspection (US DOT 2015).
- If it is impossible to confirm that no bats are present at a known roost site, one-way valves must be used to allow all bats to exit the site prior to using netting or installing permanent fixtures for exclusion. One-way valves, such as tubes, cones, mesh, or plastic flaps, can be placed over portals so that bats can leave through the valve but not return.
- Once bats are no longer present, use physical barriers to exclude them:
    - use 3/8” netting (larger mesh netting is not effective in excluding bats) (Smith and Stevenson 2015); or
    - fill roost exits/entrances or roosting crevices with a sealant or another product.
- Consult a bat specialist and/or the Community Bat Programs of BC for detailed advice on exclusion protocols.

3.4 Considerations for bridge removal/alteration/construction

For large projects where bat roosting or foraging habitat may be destroyed, it is important to assess the potential impacts on bats in the immediate and surrounding areas. This involves delineating an area of interest and planning and conducting appropriate survey work.

3.4.1 Establishing assessment area boundaries

When removing or altering a bridge that houses bats, or when constructing a new bridge, proponents of bridge projects are responsible for the potential impacts of the bridge structure itself and impacts on the area immediately around the bridge.

If bridges that are used by roosting bats are to be removed, or roost sites will be lost due to bridge alteration, the area surrounding the roost site should be evaluated to determine if there is alternative, suitable roost habitat for the species. The recommended area for assessment is the maximum average foraging distance for the species, as a radius measure. Depending on the species, bats may use habitats for foraging and/or drinking in an area that can range from 1 to 2 km up to 25 km from the roost site (see Chapter 1, Appendix A). If alternative habitat is abundant within that area, mitigation requirements may be reduced considerably. However, if alternative roosting habitat is limited, mitigation should be considered. Mitigation efforts depend on the availability of suitable habitats within the average foraging distance of the species.

3.4.2 Establishing a species list

Determining which bat species may be present is necessary to determine the area of assessment and may help identify important habitats. The following are some resources for British Columbia:

- Nagorsen, D.W. and R.M. Brigham. 1993. Bats of British Columbia. Vol.1, The mammals of British Columbia. Royal British Columbia Museum Handbook. UBC Pres, Vancouver, B.C.
- BC Species & Ecosystems Explorer (https://a100.gov.bc.ca/pub/eswp/) and NatureServe Explorer (https://explorer.natureserve.org/) have bat species range maps and information on the current status of bats in British Columbia and Canada.
- B.C. Conservation Data Centre databases (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre). Note that hibernation sites for bats are coded as secure but may be released to proponents for environmental assessment purposes.
- Species Inventory Web Explorer (http://a100.gov.bc.ca/pub/siwe/search_reset.do) provides locations of bats from provincial inventory or habitat studies.
- A list of bats in different regions of the province is available from www.bcbats.ca.
- Previous bridge-related bat surveys at the site or in the area.

3.4.3 Assessment of bat habitat in the project area

The level of effort required to assess potential bat habitat, presence, and use will vary depending on the proposed bridge management activity.

If a project area-wide habitat assessment is required, gather any relevant local survey information as background. This could include:

- reviewing local bat survey efforts at the site (in the case of a bridge to be removed/altered);
- checking the Species Inventory Web Explorer database (http://a100.gov.bc.ca/pub/siwe/search_reset.do) for locations of roost sites and maternity colonies and for reports from ecological studies in the area; and
- contacting regional wildlife biologists at ENV and FLNRORD to identify additional reports and studies.

To assess the site in the context of the region, delineate local and regional areas of impact and identify potential roosting and foraging habitat. Review available resources, such as:

- biogeoclimatic maps (https://www.for.gov.bc.ca/hre/becweb/resources/maps/index.html);
- forest cover mapping products (and/or Vegetation Resource Inventory data), which can be used to identify areas of older age-class trees that may provide roosting habitat;
- wildlife capability/suitability maps, which may identify foraging or roosting habitat (regional map products may reside in the regional Wildlife Office or the provincial Wildlife Section that coordinates wildlife mapping); and
- remote sensing resources (aerial photographs, LANDSAT images, LiDAR, or any other digital mapping resources).

Once potential bat habitats have been identified, the appropriate survey design, techniques, and intensity should be determined by an experienced bat biologist. Assessment of bat communities and their habitats should follow the provincial standards and protocols for handling bats and for data collection (RISC 1998). The *Range-wide Indiana Bat Protection and Enhancement Plan Guidelines* (USFWS et al. 2009) also provide valuable guidance on conducting bat habitat assessments.

3.4.4 New bridge construction

New construction may involve extensive forest clearing. For detailed guidance on forestry activities in bat habitat, see "Best Management Practices Guidelines for Bats in British Columbia: Chapter 5: Forestry". Key relevant points include the following:

- Minimize tree removal during all phases of construction and in all project areas (e.g., temporary work areas, alignments, main project site); clear only what is essential for project safety and implementation.
- When harvesting trees within the special management zone:
    - clearly demarcate forested areas that are to be cleared; clearly communicate to on-site workers which areas are to be cleared;
    - avoid removal of known bat roost trees;
    - avoid clearing or eliminating known foraging areas for bats;
    - retain structural elements that are important to bats, including large-diameter trees (≥ 30–50 cm diameter at breast height [dbh]);
    - retain wildlife trees (classes 2–8; especially those with cracks, peeling bark, cavities, or hollow interiors);
    - retain some smaller-dbh green trees to recruit future wildlife trees;
    - use only partial harvesting systems and retain 70% basal area if possible; and
    - respect timing windows for forest harvesting (avoid harvesting 1 May through 31 August).
- Minimize dust produced from the work site.
- Follow BMPs for bat-friendly lighting.
- If construction involves high noise levels, consider installing sound barriers, particularly if roosting bats are known to occur nearby.
- Follow the provincial guidelines for development and construction near wetlands and waterways, and for the construction of water crossings (http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/working-around-water).
- Consult "Develop with Care" guidelines (https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/best-management-practices/develop-with-care) (B.C. MOE 2014a), especially sections that refer to aquatic and riparian ecosystems (see Section 4: https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/best-management-practices/develop-with-care/dwc-section-4.pdf).

3.5 Bat-friendly lighting

Smarter lighting is the key to reducing the effects of artificial lighting on bats. For more information on reducing the impacts of temporary and permanent lighting on bats, refer to the background document "Artificial Lighting and Bats" (http://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12460). Be aware that even short-term nighttime maintenance activities that require lighting can affect bats. The following guidelines are adapted from the Bat Conservation Trust's (2014) Interim Guidelines (www.bats.org.uk/pages/bats_and_lighting.html), International Dark-Sky Association (2017) (http://darksky.org/), and US DOT (2015), and may be particularly relevant to bridge work:

- Do not directly shine light on bat roosts, especially at roost exit or entrance points and flyways.

- If operations must be conducted when bats are present, use localized lighting for the worksite.
- Minimize the spread of light from each light source: direct light specifically at task areas and use shields or accessories on lights to assist.
- When illuminating surfaces, direct lighting downward to minimize the amount of light shining upward, and use fixtures that reduce light spillage.
- Avoid using reflective surfaces under lighting fixtures.
- Consider installing temporary light screens.
- Shield sensitive areas from lighting by using vegetation or temporary close-boarded fencing until the vegetation matures.
- Consider options other than lighting. For example, reflective paint, white lining, good signage, or reflectors could be used along roadways, and lighting could be limited to high-risk areas such as intersections or crossings.
- The spectral composition of light impacts biodiversity; therefore, ensure that bridge lighting meets the technical specifications in the background document “Artificial Lighting and Bats”.
- Consider hiring a lighting specialist who will know the best location to place lighting, the use and type of lighting, and the best lighting control system for each situation. A professional lighting expert who is familiar with technology and lighting methods can integrate ecological concerns into a design plan (or model) that will mitigate the effects of required lighting. Early involvement of this expertise will produce better outcomes.

3.6 Mitigation

If work is conducted at a bridge known to be used by bats, attempt to ensure that bat roost sites are still suitable or can be restored after the work has been completed. In many cases, it will not be possible to avoid all impacts on bats and their habitats. In this case, mitigation should be considered. Implementation of mitigation measures should follow the B.C. Ministry of Environment’s mitigation procedures (B.C. MOE 2014b, 2014c). Updates and additional information on the province’s Environmental Mitigation Policy are available on the Ministry’s website (https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/environmental-guidance-and-policy/environmental-mitigation-policy).

Mitigation may involve providing alternative bat habitat to offset the loss of habitats due to development. For lost summer roosting habitat, proponents may consider constructing alternative habitat, such as bat boxes, artificial roost trees that simulate trees with loose bark (Noteman 1998; Dillingham et al. 2003), and rock roosts, based on specifications that are suitable for the geographical location, and on input from a bat specialist. Various structures have been used to enhance bat roosting habitat at bridge sites; they can be tailored to the specific bridge, the bat species occupying the site, and the geographical location (Keeley and Tuttle 1999; Johnston et al. 2004; Smith and Stevenson 2015). Assess the availability of alternative roosting habitat in the area around the bridge site based on the average foraging distance for the bat species impacted (US DOT 2015). If there is no alternative suitable roosting habitat for the species within that area, alternative roost structures could be erected to offset habitat impacts.

It is not well understood which types of artificial roost structures bat species in British Columbia prefer; therefore, a variety of locations and bat box designs, such as rocket boxes and multi-chambered boxes, should be used to provide a variety of different microclimates for roosting bats. The Community Bat Programs of BC (https://bcbats.ca/) and Bat Conservation International (https://www.batcon.org/) suggest placing several bat boxes with different solar

exposures, at least 3 m above the ground, on poles, bridges, or buildings (BCI 2021), but the locations and designs may need to be adapted based on the advice of a local bat biologist. It should also be noted that these recommendations will evolve over time and are likely to be different in different regions. The boxes should be monitored to determine their level of occupancy, a plan for their long-term maintenance should be established, and future bridge maintenance requirements should be considered when erecting artificial roost structures. New bridge construction can incorporate design features that encourage roosting bats; placement of new bridges requires consideration of existing natural features that are used by bats.

Mitigation may also include retaining or rebuilding ponds and wetland areas that provide important drinking/foraging habitat for bats within the special management zone; establishing long-term planning to retain or recruit young forest areas to provide tree roost habitat in the future; and/or replanting areas where forest clearing has disrupted connectivity corridors between roosting and drinking/foraging habitats (Gunnell et al. 2012). Habitat enhancement plans for bats should be based on the advice of a bat specialist, included in the bat management plan, and developed well in advance of bridge management activities.

Proponents may also compensate for lost habitat by protecting suitable habitat nearby. Tree-roosting bats typically use a series of roosts that are within relatively close proximity; however, the number of roosts used and the distances between roosts will vary depending on the bat species and forest type (Barclay and Kurta 2007; Carter and Menzel 2007).

Work plans should focus on maintaining the integrity of bat habitat and connectivity between roosting and foraging/drinking habitats to ensure that these habitats remain effective for bats. Site development and water use should be managed in a way that wetlands (small and large) and riparian areas are maintained. The development should also be designed to maintain contiguous patches of forest, where possible, within the development area; maintain surface vegetation and minimize erosion effects; and avoid the introduction of non-native plant species. Where possible, removal of vegetation cover should be avoided in the immediate vicinity of underground sites used by bats, such as mines and caves, because it can affect the roost's microclimate.

Any water that flows away from a construction site must meet minimum clean drinking water standards for wildlife (British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture [https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines]). If water is unsafe for consumption, the site should be made inaccessible to wildlife, including bats. Also, increased water flow and turbulence may impede a bat's ability to drink. If wetlands or riparian habitat are lost due to development, a compensation plan should be proposed for enhancing this type of habitat for bats elsewhere in the development area or region (or Landscape Unit [see Glossary]). If bat colonies are known to occur in the development area, small ponds could possibly be created to provide drinking habitat for the bats.

Construction of bat-friendly gates in portals of known roost sites is often used to control human access, for safety and liability purposes. For bridge structures that are used by bats, fencing may also be used to control human access. Gates and fencing both require special consideration prior to installation. Gates can disrupt airflow, and if improperly installed, both gates and fencing can prevent access by some bat species. There are various options for bat-friendly gating. Appropriate gate design is often site-specific because of variations in the size and type of opening, the geomorphology of the area, and the bat species using the site. Any bat-gate installation should involve an experienced bat biologist and bat-gate specialist.

To reduce the cumulative effects of developments on wildlife, attempts should be made to place all new developments in locations where disturbances to vegetation, soil, and hydrology will be minimized, such as areas where soils and vegetation have been disturbed by previous developments.

4 Reporting

Bridge workers and environmental consultants can contribute to knowledge about bat species in British Columbia by reporting information about bat sightings and bat roosts to the B.C. Ministry of Environment and Climate Change Strategy whenever possible. Due to the threat of white-nose syndrome, any observations of dead bats or bats with a white residue on their nose should be reported immediately.

4.1 Reporting bats at bridges

- Require staff and contractors who are working on bridge projects to record bat observations.
- At a minimum, record the date, location, and number of bats, or the presence of guano.
- Ideally, follow Section 3.1 and use the datasheet in Appendix 1 to record bat and bridge data.
- Submit individual observations as incidental reports (https://a100.gov.bc.ca/pub/wiof/locationForm.do)
- Submit survey data on bat presence and absence at bridges to the B.C. Wildlife Species Inventory database using the General Survey Sample Stations template (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates) or email to ENV's Small Mammal Specialist/Bat Conservation Coordinator, and inform your regional Community Bat Programs of BC (www.bcbats.ca).
- If you count bats, use the datasheet available at https://bcbats.ca/get-involved/counting-bats/.
- Submit count data to the BC Annual Bat Count https://bcbats.ca/get-involved/counting-bats/
- Do not closely approach live bats or a bat colony to obtain this information.

4.2 Reporting sick or dead bats

- Take photographs of the bat(s).
- Record an accurate location (e.g., GPS location, or mark on a topographic map), and the date and time.
- If there is a carcass, use gloves and/or a shovel, and place the carcass in a Ziploc bag with a label that includes the date, location found, and name and contact information of the finder. Do not touch bats or any wild animals with bare hands.
- Immediately contact the Wildlife Health Program (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/bats#foundabat) or a local Community Bat Program for further information (www.bcbats.ca/).

4.3 Incidental observations

If bats are observed incidentally in the development area, whether in or flying around a cave, building, bridge, or tree, report this information to the Incidental Observation database (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information).

Include the following information:

- your name and the date;
- the number of bats observed;
- the type of activity they were exhibiting;
- where they were located;
- whether pups were observed (in summer); and
- the species, if known, or enter as “bat”.

This information will enable follow-up investigation.

4.4 Reporting results of advanced bat survey work

A *Wildlife Act* permit (portal.nrs.gov.bc.ca/web/client/-/general-wildlife-permit) is required if trapping or other methods that involve touching bats are used during the project. Under the permit conditions, data and reports must be submitted to the B.C. Ministry of Environment and Climate Change Strategy and B.C. Conservation Data Centre through the B.C. Wildlife Species Inventory database (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information).

For bat capture and/or telemetry work, use the Bat Capture and Telemetry Template (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates) to report the species, gender, life stage (juvenile or adult), sexual condition (reproductive or not), weight, and size measurements of individuals captured.

Although a *Wildlife Act* permit is not required for acoustic monitoring, counts of emerging bats, or other visual surveys, it is strongly suggested that the data and reports from these activities also be submitted to the Wildlife Species Inventory database.

For acoustic surveys, use the Bat Acoustic Template (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates) to record acoustic

analysis information. Associated reporting should summarize activity by species to identify the total, average, and median number of bat passes per detector night. To facilitate comparison across studies, present activity data as the average number of bat passes per detector hour for each species or species group. Provide information on how activity by species or species group varies across seasons.

For the bat work described above, clearly describe the sampling design, including the type of sampling protocol used (e.g., bat detectors, net-nights, bridge searches). For surveys that use acoustic detectors, report any modifications to the detectors (e.g., weatherproofing), the number and placement of the detectors, detector settings, dates sampled, and considerations in establishing the sampling locations and number of detectors used. For surveys that use netting, report the number of net-nights, the dates and hours the nets were open, weather conditions, and considerations in establishing sampling locations.

5 Information needs to improve adaptive management

Bridge managers and maintenance staff can contribute to information on how and where bat species in British Columbia use bridges for roosting. The following types of information are needed to address current knowledge gaps:

- the location of bridges used by bats, the bat species present, and the timing of use, by geographic region,
- the size of bat populations using each bridge roost,
- the specific feature used for roosting,
- the characteristics of bridges where bats are found, including site, position, elevation, and aspect; ecological features, such as proximity to water and foraging habitat; entrance location, configuration, accessibility, and cover; microclimate (temperature, relative humidity) and airflow patterns; and bridge construction (materials, geometry, and complexity),
- the types/characteristics of bridges NOT used by bats, and
- how activities such as bridge maintenance, repair, and replacement, or development of features under or near bridge roosts, affect bat roosting behaviour and roost fidelity.

6 Glossary

Acoustic survey/echolocation survey: a method of detecting bats by using an ultrasonic bat detector. Detectors may be handheld (“active surveys”) or connected to an electronic system for long periods of recording independent of human observation (“passive surveys”).

Bachelor roost: a roost used by one or more males during the day.

Bat detector: any device used to render the ultrasonic calls of a bat audible to the human ear (RISC 1998).

Best Management Practices (BMPs): methods, measures, or practices designed to prevent or minimize the impacts of human-related activities or industry. Usually, BMPs are applied as a system of practices rather than a single practice (Dunster and Dunster 1996).

Cave: a natural cavity in the earth that connects with the surface, contains a zone of at least partial darkness, and is large enough to admit a human. For the purposes of cave management, this term also includes any natural extensions, such as crevices, sinkholes, pits, or any other openings that contribute to the functioning of the cave system (adapted from RISC 2003).

Crevice: a narrow crack or opening or a fissure or a cleft not large enough to admit a human. In addition to using caves, bats may roost in crevices and other cracks or surface openings within caves, in rocks, in rock outcrops, and on exposed cliff faces (Nagorsen and Brigham 1993; Nagorsen et al. 1993; Lewis 1995).

Day roost: a roost where bats rest during the day in spring/summer/fall. Types of day roosts include maternity roosts, bachelor roosts, and mixed male/non-reproductive female/yearling roosts. Use of a specific day roost may be seasonal or variable within a season.

Echolocation: an orientation system by which bats generate sounds and listen to their returning echoes to locate obstacles and prey (Nagorsen and Brigham 1993).

Ephemeral roost: a bat roost in a feature within which the characteristics that are important to bats (e.g., microclimate) may change quickly and/or unpredictably; for example, an area under sloughing tree bark.

Federal status listing of species: The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the status of Canadian wildlife. The *Species at Risk Act* (SARA) is the federal legislation for protecting Canada's natural resources, and may be applicable on both federal and private land (under certain conditions). Further information is provided on the COSEWIC website (https://www.cosewic.ca/index.php/en-ca/)

Flyway: any corridor used by bats commuting between roost and foraging areas. Flyways make excellent sites for capturing bats in mist nets and harp traps. Often delimited by physical structures such as vegetation or buildings (RISC 1998).

Forage: to hunt for food.

Goals: the intended general purpose, direction, or end result toward which an effort is directed. Goals should reflect perceived present and future need and must be capable of being effectively pursued (B.C. MOFR 2008). Goals are qualitative and are achieved by means of objectives (Dunster and Dunster 1996).

Guidelines: a set of recommended or suggested methods or actions that should be followed in most circumstances to assist administrative and planning decisions and their implementation in the field. Guidelines may consist of policy statements, procedures, or checklists. They are provided as a broad framework of recommended actions to be taken and, therefore, provide some flexibility for decision-making. Note that guidelines cannot, by definition, be mandatory (mandatory actions must be prescribed by regulations or rules) (Dunster and Dunster 1996).

Harp trap: a specialized trap designed exclusively for capturing bats (RISC 1998).

Hibernaculum: a site where one or more bats hibernate in winter (plural: hibernacula). A specific hibernaculum may be used by bats for only part of the winter or may not be used every winter.

Hibernation: a state of lethargy characterized by a reduction in body temperature and metabolic rate (Nagorsen and Brigham 1993). Bats in British Columbia hibernate in winter when cool temperatures and snow or rain make their insect prey unavailable.

Inventory: a single enumeration of an ecological system; generally conducted either as a basis for estimating potential yield or to establish a benchmark. An inventory may represent one point in time in a monitoring program. Ecological inventories may be more comprehensive and spatially/temporally discrete than monitoring activities.

Landscape Unit: an area of land and water used for long-term planning of resource management activities. It is important for designing strategies and patterns for landscape-level biodiversity and for managing other forest resources. A Landscape Unit may be used by the Deputy Minister to establish objectives for any purpose permitted under Section 2 of the *Forest Practices Code of British Columbia Act* (B.C. MOF and MELP 1999).

Maternity colony: an aggregation of females in spring, summer, or fall. The colony may include pregnant females (may not be visibly pregnant early in the season), lactating females with or without young-of-year, or post-reproductive females. A maternity colony may consist of a group of females within a single maternity roost (e.g., building, cave) or a group of females roosting singly or in small groups in close proximity (e.g., in crevices within a cliff or boulder field, in a forest stand under the sloughing bark of trees) and maintaining a long-term social relationship (Metheny et al. 2007; Kerth et al. 2011). A roost used by such a colony is called a maternity roost.

Maternity roost: a roost used outside the winter period by adult females that are capable of reproduction.

Mitigation: measures implemented to control, reduce, or eliminate a potential adverse impact of a project; includes restorative measures (EAO 2003).

Monitoring: repeated, systematic measurements conducted for a specific purpose. Monitoring is focused on measurements over time in order to detect the change toward, or away from, a stated standard or objective. Monitoring is part of the cycle of assessment and evaluation that is linked to management activities.

Night roost: a roost where bats rest at night between foraging bouts. Bats may roost singly or congregate.

Nursery colony: a type of maternity colony composed mainly of nursing females with young (summer), or an aggregation of mainly volant pups (late summer/early fall). A roost used by such a colony is called a nursery roost (C. Lausen, Wildlife Conservation Society Canada, pers. comm., 2016).

Nursery roost: a roost where females congregate to give birth and raise their young (adapted from Knight and Jones 2009). A nursery roost is a type of maternity roost.

Objective: a quantifiable, measurable, and defined target capable of attainment within a defined period. Objectives are the means by which goals are achieved, and should include four main components: (1) a statement of the desired outcome (i.e., what is to be accomplished); (2) a defined time period within which the expected outcome is to be achieved; (3) defined metrics, such as quantity, quality, or cost, so that the fulfilment of the objective can be verified; and (4) identification of who is responsible for achieving the indicated result. Desirable (but not absolutely essential) elements of objectives are a description of how they will be achieved and an indication of who will determine whether the results have been achieved. Objectives are

typically more specific and occur within a shorter timeframe than goals and serve as milestones toward goal achievement (Dunster and Dunster 1996).

Permanent roost: a roost that is available for bat use over many years and has suitable characteristics (e.g., microclimate, access) that remain stable over time. Examples of permanent roosts include caves, cliffs, mines, bridges, buildings, and large hollow trees of slow-decaying species, such as western redcedar (*Thuja plicata*).

Portal: the entrance to an adit or tunnel (Thomson 2002).

Pup: a bat born during the current year.

Rehabilitation: the restoration of ecosystem functions and processes in a degraded system or habitat (Dunster and Dunster 1996).

Reporting: the process of effectively communicating the results of monitoring and their potential implications to a target audience.

Roost: a daytime retreat or nighttime resting place.

Standards: quantifiable and measurable thresholds that are typically defined in law or regulation and that are mandatory. A statement that outlines how well something should be done rather than how it should be done. A standard does not necessarily imply fairness or equity, or an absolute knowledge of cause-and-effect linkages. Standards are typically established using a combination of best available scientific knowledge tempered by cautious use of an established safety (caution) factor (Dunster and Dunster 1996).

Provincial status listing of species (British Columbia): Provincial rankings for wildlife, plants, and ecosystems in British Columbia were developed by the Conservation Data Centre in 1994 (Harper et al. 1994). The combination of ranks for each species determines which list the species will be included in (i.e., Red, Blue, or Yellow List: https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data/red-blue-yellow-lists).

Stewardship: caring for the land and associated resources so that healthy ecosystems can be passed on to future generations (Dunster and Dunster 1996).

Swarming: behaviour associated with nocturnal flights that are made through potential hibernacula by aggregations of bats in late summer or fall (Nagorsen and Brigham 1993).

Torpor: a short-term (daily) state of inactivity achieved by lowering the body temperature and reducing the metabolic rate in order to conserve energy (Nagorsen and Brigham 1993).

Volant: capable of flying.

Yearling: a bat born in the previous reproductive year.

Young-of-year: a bat born during the current reproductive year.

7 Additional information and literature cited

7.1 Photo galleries of bats and bridges

You can find excellent photographs of bat roost sites and evidence of roosting bats online; for example:

- Bats and Transportation Infrastructure Gallery: www.bati.institute/gallery/
- White-nose Syndrome Conservation and Recovery Working Group's 2018 Acceptable management practices for bat species inhabiting transportation infrastructure. https://www.whitenosesyndrome.org/mmedia-education/acceptable-management-practices-for-bat-species-inhabiting-transportation-infrastructure

7.2 Supplemental information on bats and Best Management Practices

- White-nose Syndrome fact sheet (https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/wildlife-health/wildlife-health-documents/white-nose_syndrome_fact_sheet_march_2017.pdf)
- Ministry of Environment and Climate Change Strategy regional contact and offices (https://www2.gov.bc.ca/gov/content/environment/air-land-water/land/regional-environment-contacts)
- Karst Inventory Standards and Vulnerability Assessment Procedures for British Columbia (https://www.for.gov.bc.ca/hfd/pubs/docs/mr/Mr099.pdf)
- Karst Management Handbook for British Columbia (https://www.for.gov.bc.ca/hfp/publications/00189/Karst-Mgmt-Handbook-web.pdf)
- Copies of all official legislation (https://www.bclaws.gov.bc.ca/) for British Columbia are available online.
- Ministry of Environment and Climate Change Strategy Natural Resource Best Management Practices (https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/best-management-practices) for environmental stewardship
- Keeley, B.W. and M.D. Tuttle. 1999. Bats in American bridges. Bat Conservation International, Inc. Resource Publication No. 4. https://www.researchgate.net/publication/237268659_Bats_in_American_bridges
- US DOT. 2015. Range-wide biological assessment for transportation projects for Indiana Bat and Northern Long-eared Bat. https://www.environment.fhwa.dot.gov/ESAWebTool/Site/ibatNLEBBA.aspx#fivesix
- White-nose Syndrome Conservation and Recovery Working Group's 2018 Acceptable management practices for bat species inhabiting transportation infrastructure. https://www.whitenosesyndrome.org/mmedia-education/acceptable-management-practices-for-bat-species-inhabiting-transportation-infrastructure
- The BC Species and Ecosystems Explorer (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data/species-and-ecosystems-explorer) has information on all bat species found in British Columbia.

- Bat Conservation International (https://www.batcon.org/) has information on bat species, bat gating, and bat houses.
- For the latest information on white-nose syndrome, see the Canadian Wildlife Health Cooperative (www.cwhc-rcsf.ca/wns.php) and the B.C. Ministry of Environment and Climate Change Strategy's Wildlife Health website (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-diseases/white-nose-syndrome-wns).
- The U.S. Fish and Wildlife Service (https://www.whitenosesyndrome.org/) also provides the latest information on the spread of white-nose syndrome across North America, and up-to-date information on white-nose syndrome research.

7.3 Literature cited

Adam, M.D. and J.P. Hayes. 2000. Use of bridges as night roosts by bats in the Oregon Coast Range. Journal of Mammalogy 81:402–407.

Alberta Sustainable Resource Development (ABSRD). 2011. Recommended land use guidelines for protection of selected wildlife species and habitat within grassland and parkland natural regions of Alberta. Fish Wildlife Division. https://open.alberta.ca/publications/3054250

Altenbach, J.S., R. Sherwin, and P. Brown. 2000. Pre-mine closure bat survey and inventory techniques. In: Proceedings of Bat Conservation and Mining: A Technical Interactive Forum. St. Louis, Mo. K.C. Vories and D. Throgmorton (editors). U.S. Dep. Interior, Alton, Ill., and Coal Research Center, Southern Illinois University, Carbondale, Ill.

Arnett, E.B., W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A. Jain, G.D. Johnson, J. Kerns, R.R. Koford, C.P. Nicholson, T.J. O'Connell, M.P. Piorkowski, and R.D. Tankersley, Jr. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management 72:61–78.

Baerwald, E.F. and R.M.R. Barclay. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. Journal of Wildlife Management 75:1103–1114.

Barclay, R.M.R. 1982. Night roosting behavior of the Little Brown Bat, *Myotis lucifugus*. Journal of Mammalogy 63:464–474.

Barclay, R.M.R. and A. Kurta. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. In: Bats in forests: conservation and management. M.J. Lacki, J.P. Hayes, and A. Kurta (editors). John Hopkins University Press, Baltimore, Md., pp. 17–59.

Bat Conservation International (BCI). 2017. The bats at the bridge. https://www.batcon.org/article/the-bats-at-the-bridge/ (Accessed Nov. 2021).

Bat Conservation International (BCI). 2021. Bats & COVID-19 updates. https://www.batcon.org/bats-covid-19-updates/ (Accessed Aug. 2021).

Bat Conservation Trust. 2014. Artificial lighting and wildlife. Interim guidance: recommendations to help minimise the impact of artificial lighting. https://cdn.bats.org.uk/uploads/pdf/BCT_Interim_Guidance_Artificial_Lighting_June_2014.pdf?v=1541085199

B.C. Centre for Disease Control (B.C. CDC). 2021. Rabies. www.bccdc.ca/health-info/diseases-conditions/rabies (Accessed Aug. 2021).

Blehert, D.S., A.C. Hicks, M. Behr, C.U. Meteyer, B.M. Berlowski-Zier, E.L. Buckles, J.T.H. Coleman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2009. Bat white-nose syndrome: an emerging fungal pathogen? Science 323:227.

British Columbia Ministry of Environment (B.C. MOE). 2014a. Develop with care 2014: environmental guidelines for urban and rural land development in British Columbia. Victoria, B.C. https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/best-management-practices/develop-with-care (Accessed Mar. 2017).

British Columbia Ministry of Environment (B.C. MOE). 2014b. Procedures for mitigating impacts on environmental values (environmental mitigation procedures). Version 1.0. Victoria, B.C. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-policy-legislation/environmental-mitigation-policy/em_procedures_may27_2014.pdf

British Columbia Ministry of Environment (B.C. MOE). 2014c. Environmental mitigation policy – working document – May 13, 2014. Victoria, B.C. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-policy-legislation/environmental-mitigation-policy/em_policy_may13_2014.pdf

British Columbia Ministry of Environment (B.C. MOE). 2017. Managing bats in buildings. Environmental Protection and Sustainability, Victoria, B.C. http://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management/managing-pests/animals/bats (Accessed Nov. 2021).

British Columbia Ministry of Environment and Climate Change Strategy (B.C. MOE). 2020. Glossary for species & ecosystems at risk. Conservation Data Centre, Victoria, B.C. https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data/glossary-for-species-ecosystems-at-risk

British Columbia Ministry of Forests and Range (B.C. MOFR). 2008. Glossary of forestry terms in British Columbia. Victoria, B.C. https://www.for.gov.bc.ca/hfd/library/documents/glossary/Glossary.pdf

British Columbia Ministry of Forests and Ministry of Environment Lands and Parks (B.C. MOF and MELP). 1999. Landscape Unit planning guide. Victoria, B.C.

British Columbia Ministry of Forests, Lands and Natural Resources (B.C. FLNRO). 2014. A compendium of wildlife guidelines for industrial development projects in the north area, British Columbia. Interim guidance. Victoria, B.C.

Britzke, E.R., B.A. Slack, M.P. Armstrong, and S.C. Loeb. 2010. Effects of orientation and weatherproofing on the detection of bat echolocation calls. Journal of Fish and Wildlife Management 1:136–141.

Carter, T.C. and J.M Menzel. 2007. Behavior and day-roosting ecology of North American foliage-roosting bats. In: Bats in forests: conservation and management. M.J. Lacki, J.P. Hayes, and A. Kurta (editors). Johns Hopkins University Press, Baltimore, Md., pp. 61–81.

Centers for Disease Control and Prevention (CDC). 2020a. Histoplasmosis. Atlanta, Ga. https://www.cdc.gov/fungal/diseases/histoplasmosis/index.html (Accessed Dec. 2020).

Centers for Disease Control and Prevention (CDC). 2020b. Rabies. Atlanta, Ga. https://www.cdc.gov/rabies/index.html (Accessed Dec. 2020).

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2012. Emergency assessment concludes that three bat species are endangered in Canada. https://www.canada.ca/content/dam/eccc/migration/cosewic-cosepac/d37ab818-5f3b-44dc-9d56-ee22c63f4512/bat_emergency_assessment_press_release_final-en.pdf (Accessed Mar. 2017).

Community Bat Programs of BC. 2021. Bats and human health. www.bcbats.ca/index.php/bat-basics/bats-and-human-health (Accessed Dec. 2021).

Craig, J., M. Sarell, and S. Holroyd. 2014. Got bats? B.C. Community Bat Project frequently asked questions. Prepared for the B.C. Community Bat Project Initiative. http://www2.gov.bc.ca/assets/gov/environment/pesticides-and-pest-management/managing-pests/bats/bat_faq.pdf (Accessed Mar. 2017).

Delaney, D.K. 2002. Prioritization of threatened and endangered species sound research on army installations. U.S. Army Corps of Engineers, Engineer Research and Development Center and the Construction Engineering Research Lab, Champaign, Ill. ERDC/CERL TR-02-30.

Dillingham, C.P., S.P. Cross, and P.W. Dillingham. 2003. Two environmental factors that influence usage of bat houses in managed forests of southwestern Oregon. Northwestern Naturalist 84:20–23.

Dunster, J. and K. Dunster 1996. Dictionary of natural resource management. UBC Press, Vancouver, B.C.

Environment Canada. 2014. Little Brown Myotis, Northern Myotis and Tri-colored Bat. www.registrelep-sararegistry.gc.ca/virtual_sara/files/gen_info/fs_chauvesouris_bats_gen-v03_0215_e.pdf (Accessed Mar. 2015).

Environment and Climate Change Canada. 2018. Recovery strategy for the Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*), and Tri-colored Bat (*Perimyotis subflavus*) in Canada. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa, Ont. http://publications.gc.ca/collections/collection_2018/eccc/En3-4-308-2018-eng.pdf f (Accessed Aug. 2021).

Environmental Assessment Office (EAO). 2003. Summary guide to the British Columbia environmental assessment process. Victoria, B.C. www.llbc.leg.bc.ca/public/pubdocs/bcdocs/360560/brochure_mar_03.pdf

Erickson, G.A. et al. 2002. Bat and bridges technical bulletin (Hitch hikers guide to bat roosts). California Department of Transportation, Sacramento, Calif.

Gargas, A., M.T. Trest, M. Christensen, T.J. Volk, and D.S. Blehert. 2009. *Geomyces destructans* sp. *nov*. associated with bat white-nose syndrome. Mycotaxon 108:147–154.

Garrett, P. 1996. “Attention motorists…the bats have landed on our bridge!” U.S. Department of Transportation, Federal Highway Administration. Public Roads 59(3). https://www.fhwa.dot.gov/publications/publicroads/96winter/p96wi12.cfm (Accessed Aug. 2021).

Grindal, S.D., T.S. Collard, R.M. Brigham, and R.M.R. Barclay. 1992. The influence of precipitation on reproduction by Myotis bats in British Columbia. American Midland Naturalist 128:339–344.

Gunnell, K., G. Grant, and C. Williams. 2012. Landscape and urban design for bats and biodiversity. Bat Conservation Trust, UK. https://cdn.bats.org.uk/uploads/pdf/Our%20Work/Landscape_and_urban_design_for_bats_and_biodiversityweb.pdf?v=1541085229 (Accessed Mar. 2017).

Harper, B., S. Cannings, D. Fraser, and W.T. Munro. 1994. Provincial lists of species at risk. In: Biodiversity in British Columbia. L.E. Harding and E. McCullum (editors). Canadian Wildlife Service, Delta, B.C., pp. 16–23.

HealthLinkBC. 2021. Hantavirus pulmonary syndrome. https://www.healthlinkbc.ca/healthlinkbc-files/hantavirus-pulmonary-syndrome (Accessed Aug. 2021).

Holroyd, S.L. 1993. Influences of some extrinsic and intrinsic factors on reproduction by big brown bats (*Eptesicus fuscus*) in southeastern Alberta. MSc thesis. University of Calgary, Calgary, Alta.

International Dark-Sky Association. 2017. http://darksky.org/.

Johnson, J.B., J.E. Gates, and N.P. Zegre. 2011. Monitoring seasonal bat activity on a coastal barrier island in Maryland, USA. Environmental Monitoring and Assessment 173:685–699.

Johnston, D., G. Tatarian, and E. Pierson. 2004. California bat mitigation, techniques, solutions, and effectiveness. Prepared for California Department of Transportation and Dr. G.R. Trapp, California State University Sacramento Foundation, Sacramento, Calif. Project No. 2394-01. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=10334 (Accessed Mar. 2017).

Jung, T.S., I.D. Thompson, R.D. Titman, and A.P. Applejohn. 1999. Habitat selection by forest bats in relation to mixed-wood stand types and structure in central Ontario. Journal of Wildlife Management 63:1306–1319.

Kalcounis, M.C. and R.M. Brigham. 1998. Secondary use of aspen cavities by tree roosting big brown bats. Journal of Wildlife Management 62:603–611.

Keeley, B.W. and M.D. Tuttle. 1999. Bats in American bridges. Bat Conservation International Incorporated. Resource Publication No. 4.

Kerth, G., N. Perony, and F. Schweitzer. 2011. Bats are able to maintain long-term social relationships despite the high fission-fusion dynamics of their groups. Proceedings of the Royal Society of London 278B:2761–2767.

Knight, T. and G. Jones. 2009. Importance of night roosts for bat conservation: roosting behaviour of the lesser horseshoe bat *Rhinolophus hipposideros*. Endangered Species Research 8:79–86.

Kunz, T.H. 2003. Censusing bats: challenges, solutions and sampling biases. In: Monitoring trends in bat populations of the United States and territories: Problems and prospects. T.J. O'Shea and M.A. Bogan (editors). U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report USGS/BRD/ITR-2003-0003.

Kunz, T.H., E.B. Arnett, B.M. Cooper, W.P. Erickson, R.P. Larkin, T. Mabee, M.L. Morrison, M.D. Strickland, and J.M. Szewczak. 2007. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. Journal of Wildlife Management 71:2449–2486.

Lacki, M.J. and M.D. Baker. 2007. Day roosts of female Fringed Myotis (*Myotis thysanodes*) in xeric forests of the Pacific Northwest. Journal of Mammology 88:967–973.

Lewis, S.E. 1995. Roost fidelity of bats: a review. Journal of Mammalogy 76:481–496.

Metheny, J.D., M.C. Kalcounis-Rüppell, K. Kolar., C.K.R. Willis, and R.M. Brigham. 2007. Genetic relationships of roost-mates in a fission-fusion society of tree-roosting big brown bats. Behavioral Ecology and Sociobiology 62:1043–1051.

Minnis, A.M. and D.L. Lindner. 2013. Phylogenetic evaluation of *Geomyces* and allies reveals no close relatives of *Pseudogymnoascus destructans*, comb. nov., in bat hibernacula of eastern North America. Fungal Biology 117:638–648.

Nagorsen, D.W. and R.M. Brigham. 1993. Bats of British Columbia. Vol. 1, The mammals of British Columbia. Royal British Columbia Museum Handbook. UBC Press, Vancouver, B.C.

Nagorsen, D.W., A.A. Bryant, D. Kerridge, G. Roberts, A. Roberts, and M.J. Sarell. 1993. Winter bat records for British Columbia. Northwestern Naturalist 74:61–66.

Noteman, L. 1998. Hidden housing – artificial bark for bats. BATS Magazine 16(3). https://www.batcon.org/article/hidden-housing-artificial-bark-for-bats/

Ommundsen, P., C. Lausen, and L. Matthias. 2017. First acoustic records of the Brazilian Free-tailed Bat (*Tadarida brasiliensis*) in British Columbia. Northwestern Naturalist 98:132–136.

Ontario Ministry of Health and Long-term Care (MHLC). 2013. White nose syndrome in bats. www.health.gov.on.ca/en/public/publications/pubhealth/whitenose.aspx

Perlmeter, S.I. 1996. Bats and bridges: patterns of night roost activity in the Willamette National Forest. In: Bats and forests symposium. Working Paper Vol. 23, No. 1996, pp. 132–150.

Quebec Ministère des Ressources naturelles et de la Faune (MRNF). 2010. White-nose syndrome in bat populations: the presence of the syndrome is confirmed in Quebec. (Translation). https://caves.org/WNS/WNS%20Quebec_Press_Release%20April%2012.pdf (Accessed Mar. 2014).

Resources Information Standards Committee (RISC). 1998. Inventory methods for bats: standards for components of British Columbia's biodiversity No. 20. Ver. 2.0. B.C. Ministry of Environment, Lands and Parks, Victoria, B.C.

Resources Information Standards Committee (RISC). 2003. Karst inventory standards and vulnerability assessment procedures for British Columbia. Ver. 2.0. Prepared by B.C. Ministry of Forests Research Branch for the Karst Task Force, Victoria, B.C.

Sherwin, R.E., J.S. Altenbach, and D.L. Waldien. 2009. Managing abandoned mines for bats. Bat Conservation International Inc., Austin, Tex.

Smith, H.J. and J.S. Stevenson. 2015. Best management practices for bat species inhabiting transportation infrastructure. White-nose Syndrome National Response Plan. https://issuu.com/rdwildlifemanagement/docs/crwg__bats_in_bridges__bmps___17_no

Texas Department of Transportation. 2021. Bats 'n' bridges. www.dot.state.tx.us/env/pdf/publicat/Bats.pdf (Accessed Aug. 2021).

Thomson, B. 2002. Australian handbook for the conservation of bats in mines and artificial cave-bat habitats. Australian Centre for Mining Environmental Research, Melbourne, Australia.

Tuttle, M.D. 2017. Rabies in perspective. www.merlintuttle.com/resources-2/rabies-in-perspective/ (Accessed Feb. 2017).

United States Department of Agriculture (USDA) Forest Service. 2012. Forest Service extends closure of abandoned mines and caves as new studies indicate 5.5 million bats have died: closure seeks to protect bat species from white-nose syndrome. Golden, Colo. https://s3.us-west-2.amazonaws.com/prod-is-cms-assets/wns/prod/83bfe910-8d3b-11e9-ad22-19882a049409-nr_wnsclosureorder_final_7-31-12.pdf (Accessed Mar. 2017).

United States Department of Transportation (US DOT). 2015. Range-wide biological assessment for transportation projects for Indiana Bat and Northern Long-eared Bat. Federal Highway Administration and Federal Railroad Administration. https://www.environment.fhwa.dot.gov/ESAWebTool/Site/ibatNLEBBA.aspx#fn3 (Accessed Mar. 2017).

United States Fish and Wildlife Service (USFWS). 2009. Range-wide Indiana Bat Protection and Enhancement Plan guidelines. Office of Surface Mining Reclamation and Enforcement, and Interstate Mining Compact Commission. https://www.fws.gov/frankfort/pdf/INBATPEPGuidelines.pdf

Washington Department of Fish and Wildlife (WDFW). 2021.White-nose syndrome in bats. https://wdfw.wa.gov/species-habitats/diseases/bat-white-nose (Accessed Aug. 2021).

APPENDIX 1: EXAMPLE DATASHEET FOR BASIC BAT SURVEYS AT BRIDGES

Survey information		
Year Month Day	Time	Observers

Bridge identification	
Bridge name:	
Road/Hwy/Railway name:	Km marker:
Coordinates (Dec. Degree or UTM): Zone: X:	Y:
Region (circle): Cariboo | Kootenay | Lower Mainland | Okanagan | Omineca | Peace | Skeena Thompson | Vancouver Island	
MOTI ID if known	Proposed management activity:

Bridge description		
Bridge type if known (circle): Truss | Trestle | Steel I-beam | Pre-Stressed Concrete Girder/T-Beam | Cast-in-place | Adjacent/Parallel Box Girder | Flat Slab/Box | Wood Girder | Culvert | Other | Unk		
Abutment/Back wall: Wood | Concrete | Metal | NA	Underdeck: Wood | Concrete | Metal	
Beams: Wood | Concrete | Metal | NA	Columns: Wood | Concrete | Metal | NA	Creosote? Y / N
Bridge is for: Vehicle | Train | Bike | Pedestrian | Abandoned/Impassable | Other	Crossing type - bridge is over: Road | Railway | Path/Water | Other	
Amount of traffic: None | Quiet | Moderate | Busy	Water currently under bridge? No Yes	
Flying space (height) from beams/deck to surface below (water, plants, road, etc.) (metres)		
Habitat around bridge (within 100 m, estimate % of each): Forest _____% Open_____% Roads____% Urban____ % Comments (e.g., tree species):		

Bat survey results	
Bat sign (Select all that apply): NONE | Bats visible (live/dead) | Pups visible (live/dead) | Noises | Insect wings/pieces | Urine/body oil staining | Guano	
Location of bat sign (circle where, and indicate what) Where (circle)	What (type of sign; e.g., dead bat, guano)
• In crevices formed between two beams • Crevices in abutments • In expansion joints • On vertical surfaces of back wall • Exposed sides of beams or columns • On ground below bridge • Other – describe	
Guano amount in biggest pile (circle one): NO GUANO | Sparse: 1–30 pellets | Some: 30 pellets – 1 cup | Lots >> 1 cup | N/A - DISPERSED	
Guano is: Dispersed (typical of night roosting) | Concentrated below crevices (typical of day roosting)	

Guano collected: No / Yes	Guano sample label:

Bat survey results *(Continued)*
Roost assessment (circle) — Night: Likely / Unlikely / Unk | Day: Likely / Unlikely / Unk Maternity: Likely / Unlikely / Unk Comments:

Bat count detail	
Emergence count done? (circle) Yes | No If Yes, fill out BC Annual Bat Count Form If Yes, Date: Year_____ Month_____ Day_____	Other (circle): Acoustic recording | Infrared camera | Video recording

Bird observations	
Nests? (circle) Yes | No	Nest type: Cup | Mud Gourd | Hole | Other
Swallows flying? (circle) Yes | No	
Species observed, other comments:	

Photos taken? (circle) Yes | No
(Take wide angle top and bottom; both sides/directions; roost crevices, guano; visible bats…)

Comments:

APPENDIX 2: ADVANCED BAT SURVEYS AT BRIDGES

Information on what type of roost a feature provides (maternity, day, night), detailed seasonal timing of use, and information on the community of bats present (e.g., species, gender, age) is often important to inform management actions. Advanced surveys can be conducted after a basic bat survey (Section 3.1.1) to provide this more detailed information. Techniques such as visual surveys/emergence counts, acoustic monitoring, capture, and radio- or PIT-tagging may be required. Detailed information can be found in the RISC standards for bat inventory (https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/bats.pdf).

- Because bats may use a feature in one season but not in others, or in some years but not in others, surveys must be rigorous and repeated to determine with certainty that bats do not use a feature.
- Sampling must encompass a variety of weather conditions and seasons. Poor weather conditions, such as rain, cold temperatures, or high wind, can cause bats to remain torpid in their roosts, which results in low capture rates in mist nets at sampling stations. Repeated sampling is important because bats may use a series of roosts in summer and winter; a roost that appears to be unoccupied during one or two sampling sessions might be important to a local bat population at other times of the year.
- To conclude that bats do not use a feature, surveys should be conducted repeatedly using different techniques (e.g., visual inspection and acoustic monitoring), in different seasons throughout the year, and ideally for more than one year. Two years of non-detection of bat acoustic activity is required before a site is assessed as "not in use by bats" (Altenbach et al. 2000).
- For repeated surveying of a feature to determine bat usage, acoustic surveys are likely the most cost-effective and efficient because the equipment can record data automatically and can be left to collect data over a long period.
- Surveyors should use techniques that minimize disturbance to bats. Acoustic surveys and visual surveys, including roost exit counts and passive acoustic detectors deployed at entrances to roost features, are the least intrusive methods of surveying bat use of a feature. They can be used in combination with netting to determine bat use of a feature.
- Note that the RISC (1998) standards for bat inventories are the minimum standards required. Surveyors should follow the protocols in the RISC guidelines, supplemented by the bridge-specific methods outlined in this document and discussion with a bat biologist. The choice of technique for assessing bat habitat use and other parameters at a site will depend on site characteristics and the level of expected impact from bridge management activity. The decision about which survey method and assessment design to use will require the expertise of a bat biologist.

EXIT/VISUAL SURVEYS

Visual counts at bridge roosts during bat emergence (when bats exit around sunset to forage) are useful for determining colony size. Multiple observers may be needed at sites with multiple exit locations, and multiple counts may be needed at roost locations to obtain an accurate assessment of bat numbers, given that bats may move between roosts.

Where exit/visual surveys are used to confirm the numbers of bats using a roost, the feature should be surveyed at least twice during the season of suspected use. If the goal is solely to confirm use by bats, a second night of surveying is not required if bats are present.

ACOUSTIC SURVEYS

Passive acoustic sensors (bat detectors), which record the echolocation calls of bats, can provide information on bat presence, temporal and spatial patterns of bat activity, limited species identification, and very limited information on relative intensity of habitat use. As with visual surveys, acoustic monitoring can be used to assess roosting, swarming, and foraging/drinking habitat use, and bat activity in all seasons.

Bat activity at a site can vary widely depending on the season, weather, and temperature, and on changes in insect abundance (Arnett et al. 2008; Baerwald and Barclay 2011; Johnson et al. 2011); therefore, it is difficult to do any comparative analysis of acoustic data unless there are accompanying metrological data (minimum temperature, precipitation, wind speed, barometric pressure, and moon phase). Timing and duration of surveys, acoustic sensor deployment design, and basic equipment are described in the RISC (1998) standards document.

Acoustic monitoring at a bridge site may detect patterns of bat behaviour which can suggest how bats are using the area. A sudden pulse of activity at a bridge site within the first hour past sunset, accompanied by another pulse (perhaps not as strong) in the hours just before sunrise, may indicate roosting bats are leaving and returning from nightly foraging bouts. A pulse of activity well after sunset could indicate that there is a night roost at the bridge. Small pulses of activity detected through the evening may indicate that bats are foraging along waterways under the bridge.

- Record continuously and autonomously from 30 minutes before sunset to 30 minutes after sunrise on multiple nights.
- Collect acoustic data over the entire season of suspected use.
- Weatherproof bat detectors as appropriate. If waterproofing is required, detector microphones should have a rain hat system or sound reflector, where appropriate for the brand of detector used (Kunz et al. 2007). Note that the waterproofing system may influence the data recorded (e.g., Britzke et al. 2010); all reporting should include a clear description of any weatherproofing used.
- Analyze acoustic data to determine if there is evidence of bat use of the feature, the season and timing of use, and the bat species or species group present. If the acoustic data indicate that bats may be using the feature, a visual survey/roost exit count can confirm use and provide information on how many bats are using the feature.
- Analyzed acoustic data should be submitted to the British Columbia government using the Bat Acoustic Template (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates).

CAPTURE SURVEYS

Mist nets and harp traps are used to capture bats to confirm species identity; assess age, sex, and reproductive status; collect genetic samples; and affix radio-transmitters or PIT tags. These methods are often used once visual and acoustic monitoring have confirmed the presence of bats at a site.

- The capture and handling of bats can be done only by experienced bat biologists who have a valid British Columbia *Wildlife Act* research permit. Precautions and protocols outlined in the provincial standards (RISC 1998) should be followed, as well as current Canadian Wildlife Health Cooperative decontamination protocols for preventing the spread of white-nose syndrome (www.cwhc-rcsf.ca/bat_health_resources.php).

- If using capture to determine usage of a feature, sampling should be conducted at least twice during the suspected season of use for at least 1 year and preferably 2 years. Acoustic data should be collected to confirm that bats do not use the feature.
- A standard bat identification key, such as Nagorsen and Brigham (1993), should be used to identify bats in the field. If a positive identification is required, all cryptic species or those that are impossible to identify in the hand, such as some of the Myotis species, will have to be identified by genetic analysis. For those species, a guano or tissue sample must be obtained to enable analysis.

OTHER TECHNIQUES

Radio-telemetry can be extremely useful for determining the location of summer day roosts (Lacki and Baker 2007) and night roosts, and for determining spatial patterns of habitat use. However, it is less useful for determining the location of winter hibernation sites or roosts deep in mines and caves because the radio signal may be blocked by the rock. Use of this technique in the fall may identify the location of swarming sites, which could be surveyed subsequently to determine if they are used as hibernation sites.

Infrared monitoring systems use remote counting devices and infrared beams directed across entrance points of bat roosts or other high-activity areas to count bats that “break” the beams (Sherwin et al. 2009). The system gives an index of activity but does not count individuals.

PIT (passive integrated transponder) tags can be used on known populations and can be effective in mark-recapture studies (Kunz 2003). PIT tag “readers” can remotely read the PIT tag as the bat flies past; however, the success of this technique depends on the availability of a specific location where bats pass by the “reader” close enough that their PIT tag can be read.

The use of radio-telemetry, infrared monitors, or PIT tagging should be discussed with an experienced bat biologist and should follow all precautions and protocols outlined in the provincial standards (RISC 1998).