Best Management Practices for Bats in British Columbia

Chapter 4: Wind power developments

Updated: September 2025

BRITISH COLUMBIA
Ministry of Water, Land and Resource Stewardship

Version tracking table

Year	Updates
2016	Original BMP document published.
2023	4.1 Updated data submission protocols – all survey data, including bat fatality data, searcher efficiency, scavenger rate, and summarized acoustic data, to be submitted to BC Wildlife Species Inventory database. 4.1 Summarized acoustic data also submitted to the North American Bat Monitoring Program.
2025	3.1 Siting of turbines away from hibernacula and high-quality bat summer roosting and foraging habitat is emphasized. 3.3.1 Two years of pre-construction acoustic monitoring is no longer required. 3.3.1 Revised fatality targets that, if exceeded during a three-year running average of monitoring results, may trigger additional mitigation and monitoring. 3.3.2 Feathering or braking of turbine blades to slow or prevent blade rotation when not generating, from 30 min before sunset to 30 min after sunrise, Mar 15 – Oct 15. 3.3.2 Operational curtailment of turbines from 30 min before sunset to 30 min after sunrise, from Jul 15 – Oct 15, when wind speed ≤ 6 m per second OR implementation of a smart curtailment system (e.g., algorithm- or bat activity-based). 3.3.2 Optional adjustments to the standard curtailment schedule after Year 3 or to the smart curtailment schedule after Year 1 based on monitoring results. 3.3.3 Acoustic and fatality monitoring for at least three years from start of turbine operations. 3.3.4 Offsets are to be considered for residual impacts remaining after reasonable mitigation efforts have been taken. Offsets are to be developed through discussion with the regulator. Appendix 1, 2 - Survey methodologies moved to Appendices.

Executive Summary

The British Columbia Ministry of Water, Land and Resource Stewardship developed this document for agencies, wind energy proponents, researchers and consultants to provide guidance on how to minimize impacts to bats as a result of activities associated with wind power development in British Columbia (B.C.). In all project phases, consult the Environmental Mitigation Policy for B.C. and take measures to avoid impact, minimize adverse impacts, restore on-site values and offset residual adverse impacts (B.C. Ministry of Environment 2014a, b).

This document provides general guidelines only. Bat management plans for individual projects will be developed by proponents, their qualified professionals and regulatory authorities. The original document and the updates were reviewed and improved by comments from biologists both within and outside government, stewardship groups and industry representatives.

Best Management Practices for Bats in British Columbia: Wind Power Developments is one chapter of a larger strategy providing guidelines to resource sectors most likely to impact bats and their habitats. The strategy's introductory chapter reviews bat species, distribution and ecology in B.C. and provides the biological background against which the Best Management Practices guidance in later resource-specific chapters can be understood.

Each industry- and activity-specific chapter follows a similar structure. Section 1 highlights aspects of bat ecology, behaviour and distribution that may be impacted or may benefit from a specific industry or activity (for example, mining, development of wind power or caving). Section 2 describes the activities associated with a specific industry or activities that are most likely to impact bats and their habitats. Section 3 outlines Best Management Practices (BMPs). Section 4 lists monitoring and reporting requirements. Section 5 outlines knowledge gaps and information needed to inform future BMP updates related to various industries and activities, as part of an adaptive management approach. Appendices include a description of various bat survey methods that may be employed.

Some of the issues discussed in this document are subject to ongoing research (such as species and levels of fatalities at wind developments in different parts of the province, and best methods of mitigating impacts). As such, this is a living document that will be updated in response to emerging changes. Specifically, a research consortium will access data from operational windfarms and review monitoring results and effectiveness of mitigation measures. This information will be used to inform updates to the BMP document after three years of the start of operations of the 2024 Call for Power successful proponents.

Compared to traditional power generation such as hydro-electric dams, wind power is a recent and growing sector in B.C. Originally, impact assessments at wind energy developments concentrated largely on their impact on birds, primarily raptors and migratory passerines. However, in 2003 a large number of bat fatalities were noted at a development in West Virginia. Since then, greater attention has been paid to the effect of wind power developments on bats, with bat fatalities recorded at facilities worldwide. Across North America, research suggests bat fatalities now outnumber bird fatalities at wind power developments, with estimates of thousands of bat fatalities per year along forested ridgetops. Estimates of fatality rates suggest hundreds of thousands of bats are killed cumulatively in North America every year because of wind power development, posing a high risk of extinction to at least one migratory species. This chapter outlines activities to identify and mitigate potential or actual impacts to bats during each phase of a wind power development: pre-construction and construction (development phases), and post-construction (operational phase).

All activities related to assessing the quality of bat habitat or the impact of activities on bats must involve a qualified environmental practitioner (Q.E.P.) or B.C. Registered Professional Biologist (B.C. R.P.Bio.) as per the B.C. Professional Governance Act (2018).

Acknowledgements

This chapter of Best Management Practices Guidelines for Bats in British Columbia was originally written by Dr. Vanessa Craig (EcoLogic Research) and Susan Holroyd (Holroyd Consulting). This document is based on the Bat Conservation Strategy for British Columbia and Alberta (Craig and Holroyd 2004). Input and review was originally provided by Dr. Purnima Govindarajulu (B.C. Ministry of Environment), Lorraine Andrusiak (Keystone Wildlife), Dr. Cori Lausen (Wildlife Conservation Society Canada), Dr. Rhonda Millikin (EchoTrack), David Nagorsen (Mammalia Consulting), Mike Sarell (Ophiuchus Consulting), Dr. Helen Schwantje (Ministry of Forests, Lands, and Natural Resource Operations), Dan Bate (B.C. Ministry of Forests, Lands, and Natural Resource Operations), Sean Moore and Teresa Morris (B.C. Environmental Assessment Office), Wendy Easton (Environment Canada), and representatives from Clean Energy B.C., the Canadian Wind Energy Association, and the B.C. Bat Action Team Wind Energy Committee. Thanks to everyone who provided photos free of cost. Thanks to Purnima Govindarajulu, Al Hicks, Ted Down, Dave Fraser, and Brenda Hartley for facilitating discussions with wind energy industry representatives and for facilitating the review and approval process. Funding was provided by the B.C. Ministry of Environment and the Habitat Conservation Trust Foundation. Updates for 2025 were done by Mandy Kellner, Leigh Anne Isaac, and Purnima Govindarajulu, Conservation Science Section, B.C. Ministry of Water, Land and Resource Stewardship. Representatives from Clean Energy BC and the Canadian Renewable Energy Association provided valuable comments to improve the 2025 version.

Photo front page: Wind development with radar setup. Photo: R. Millikin.

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Introduction

Purpose and scope

This document is written for government agencies, wind power development proponents, researchers and consultants that review, plan, assess, implement and or monitor wind power developments. This guidance[1] document is a summary of currently available scientific information and protocols relevant to considering and minimizing adverse effects on bats when designing and operating wind power developments.

Wind power is a developing industry in B.C. Because of the potential adverse impacts of wind development activities on bat populations, implementing these Best Management Practices (BMPs) during the development (pre-construction and construction) and operation (post-construction) of wind power projects is important. Proponents can show due diligence by using these recommendations to support their management actions or providing a rationale for a different approach. In all project phases, consult the Environmental Mitigation Policy for B.C. and take measures to avoid impact, minimize adverse impacts, restore on-site values and offset residual adverse impacts (B.C. Ministry of Environment 2014 a, b).

These are general guidelines, and this document does not have regulatory intent. Project-specific details will need to be developed by the proponent and their professional biologist team based on site conditions, baseline data and other parameters. The proposed project details will be reviewed by provincial regulatory agencies responsible for assessing wind projects. These guidelines and how they fit into the regulatory review of wind projects should be discussed with the appropriate regulatory agency.

Research and inventory priorities outlined in this document will provide wildlife professionals and bat researchers with information that will inform adaptive management and future updates to BMPs. Common goals and priorities of industry and researchers can be met with collaboration and cooperation. Data collected at the site about timing, location and levels of bat activity in the post-construction phase can be used to develop adaptive management plans over time. As additional data are collected, these BMPs will be revised to reflect the updated information.

Note that all impact assessments and surveys for bats should use the services of an appropriately trained and experienced QEP. There are many considerations and limitations when choosing different approaches to inventory and or study these nocturnal animals. Additionally, a thorough understanding of the complexities of bat behaviour, including seasonal movements, habitat requirements, thermoregulation and echolocation, is essential to interpret the data and assess habitats for bats.

[1] Guidance refers to 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; such actions are prescribed by regulations or rules (Dunster and Dunster 1996).

How to use this document

Best Management Practices for Bats in British Columbia, Chapter 4: Wind Power Developments is one part of a larger strategy identifying a number of resource sectors in B.C. most likely to impact bats and their habitats. The strategy's introductory chapter includes a review of bat species, distribution and ecology in B.C. and provides the biological background for which the Best Management Practices guidance in later resource-specific chapters can be understood. Other chapters in the Best Management Practices for Bats strategy may also be relevant to wind power development.

Each industry- or activity-specific chapter follows a similar structure. Section 1 highlights aspects of bat ecology, behaviour and distribution that may be impacted or may benefit from that specific industry or activity. Section 2 describes the activities associated with a specific industry or activities that are most likely to impact bats and their habitats. Section 3 outlines Best Management Practices. Section 4 lists data submission and reporting priorities. Section 5 outlines knowledge gaps and information needed to support adaptive management. The glossary in Section 6 defines technical terms used in the chapter. Section 7 provides links to additional information on bats and wind power development. Appendices contain additional survey methodology.

Some of the issues discussed in this document are subject to ongoing research (such as how bats perceive turbines, which species are most vulnerable, and the status of white-nose syndrome), and this document will be updated as information becomes available. As this is a living document, proponents and researchers should ensure they have the latest version before commencing activities.

All activities related to assessing the quality of bat habitat or the impact of activities on bats should engage an experienced bat biologist and B.C. Registered Professional Biologist.

Objectives

The objectives of this document are to:

1. Describe the primary bat conservation issues regarding wind power developments in B.C. (Sections 1 and 2)
2. Describe best management practices (BMPs) based on existing knowledge to use during pre- and post- construction phases at wind power development sites (Section 3)
3. Clarify data submission and reporting requirements (Section 4)
4. Promote an adaptive management strategy by using submitted data to update and improve BMPs (Sections 3 and 5)

Potential impacts of wind power development on bats

Background

Wind power is a developing energy sector in B.C. and adjacent jurisdictions. As of October 2024, there were 337 wind power developments in Canada (Canadian Renewable Energy Association 2024). Wind power developments are operating in every province, the Yukon and the Northwest

Territories (Canadian Renewable Energy Association 2024). In B.C., by December 2024, there were 11 operating wind power developments with a combined capacity of approximately 743 MW (Canadian Renewable Energy Association 2024).

Development of a wind facility involves the installation of turbines, usually in a linear series or an array, in areas that typically receive high and persistent winds. This document identifies two types of wind power developments: onshore (land-based) and offshore (built on water).

Impact assessments at wind power developments originally concentrated on the effects on birds, primarily raptors and migratory passerines. However, in 2003 a large number of bat fatalities (estimated at 1000-4000 bats) was noted at an onshore development in West Virginia (Kerns and Kerlinger 2004; Arnett et al. 2008). High numbers of bat fatalities were found at the same site in 2004 and subsequently at developments in Pennsylvania and Tennessee (Arnett et al. 2008). All of these developments were located along forested ridges. Since then, greater attention has been paid to the effect of wind power developments on bats; see review in Arnett et al. (2008).

Data from the United States and Canada reveal that bat fatalities outnumber bird fatalities at many wind power developments (Barclay et al. 2007; Baerwald et al. 2009; Ellison 2012; Smallwood 2013; Bird Studies Canada et al. 2018). Researchers have estimated that cumulatively, hundreds of thousands of bats may be killed annually in North America at wind power developments (Kunz et al. 2007b; Cryan 2011; Hayes 2013; Smallwood 2013, Bird Studies Canada et al. 2018, COSEWIC 2023). Because carcass searches can only be conducted on land, only fatality rates at land-based facilities can be assessed. Fatality rates at developments built on the water are unknown.

How bats are affected

Direct mortality

At operational wind power developments, most bat deaths at turbines are due to blunt force trauma from collisions. This direct mortality at windfarms is considered the main factor in declines of migratory bats (Hoary, Silver-haired, and Eastern Red Bats) and may lead to rapid extinction (Frick et al. 2017, COSEWIC 2023) as the number and rate of fatalities at wind farms may exceed the reproductive rate of migratory bat populations.

Fatality rates of bats per turbine at land-based developments vary substantially among wind power developments. Lack of standardization of survey methodology and analysis methods across projects makes it difficult to compare fatality rates. Current estimates of bat fatalities at land-based developments range from close to zero dead bats per turbine per year to almost 70 dead bats per turbine per year recorded at a site along forested ridges in the Eastern U.S. (Arnett et al. 2008). In terms of fatalities per MW, fatality estimates at developments in the contiguous U.S. range from 0.2 per MW to 53.3 per MW (Hayes 2013) including a median estimate of 2.7 bats per MW (AWWI 2018).

In Western Canada, fatalities reported from wind power developments have ranged between no bats per turbine per year up to approximately 19 bats per turbine per year (Barclay et al. 2007; Arnett et al. 2008; Hemmera 2011; Stantec 2012a, b; Bird Studies Canada et al. 2018). Looking specifically at B.C., mortality rate estimates from limited data at eight sites under no curtailment regime varied from 0-6.6 bats per turbine per year or 0-2.3 bat per MW.

Removal of roosting habitat

Forest clearing may result in the loss of potential tree roost habitat. Many bat species in B.C. use tree roosts (Chapter 1, Section 4). Bats roost under loose bark, in tree cavities or openings, or in foliage, with roost requirements differing among species, sexes and reproductive status (Nagorsen and Brigham 1993; Crampton and Barclay 1998; Barclay and Brigham 2001; Parsons et al. 2003; Willis et al. 2003). Suitable roosting habitat is a critical resource for bats. Clearing large forest patches may disturb bats and limit their ability to reproduce that year or may result in direct mortality of adult and juvenile bats.

Tree removal or land clearing can also affect the suitability of cave or mine roosts. In some areas, bats switch roosts between caves and trees as weather changes, requiring proximity of the two types of roosts. Negative impacts on usable cave and or mine roost habitat from forestry activities also occur through indirect effects such as changes to microclimate (Hill and Smith 1984; Nieland 2000). Removal of boulders or destruction of talus slopes can also affect roosting and hibernating habitat. See B.C.'s BMPs for Bats: Chapters 2 or 3 for information on activity around mines and cave and crevice habitat for bats.

Loss or degradation of foraging and drinking habitat

Riparian habitat, ponds and wetlands are important foraging and drinking habitat for many species of bats (Brigham et al. 1992; Lunde and Harestad 1986; Grindal 1998; Millikin 2005); open water is a critical resource for bats (Christy and West 1993). As with any construction activity and development, changes in drainage or loss or degradation of riparian areas can negatively affect bats.

Blasting

Noise and physical disturbance from blasting, dust or noise (vibrations) as a result of site preparation and construction can affect adjacent bat colonies (forest- or rock-roosting) in summer or winter. Blasting activities, in addition to noise disturbance, can directly affect the integrity of underground roosting habitat in caves, mines, cliffs or rock fields through inadvertent collapse of features, especially because the habitats significant for bats may not be obvious unless acoustic surveys and other methods are used to detect bat presence and use. Blasting may also result in direct habitat loss through removal of cliffs used for roosting, or it may affect foraging or drinking habitats.

Species affected

In B.C., seven bat species have been confirmed dead at wind facilities as of 2024 (Table 1). This list includes two resident bat species that are Blue-listed in B.C. and federally listed on Schedule 1 of the Species at Risk Act (Little Brown Myotis and the Northern Myotis) as well as the three migratory bats assessed as Endangered by COSEWIC (Silver-haired, Hoary, and Eastern Red Bats, COSEWIC 2023). Species that have not yet been recorded as fatalities at wind power developments still may be at risk as projects are developed in different areas of the province where different bat species may be present.

Bats are known to be killed at wind power developments on land when migrating. Most bats move seasonally from hibernation areas to summer roosting areas and back again. Bat species vary in the distances they migrate and can be broken into three categories: long-distance, regional and resident (Fleming and Eby 2003). In general, ‘migratory bats’ refers to a few bat species which move over 1,000 km (long-distance migrants); this category includes Red, Hoary and Silver-haired Bats in North America (Baerwald et al. 2014; Cryan et al. 2014b). The migratory behaviour of Silver-haired Bats in B.C.is not fully understood, and there is evidence of year-round fidelity to sites by males in southern reaches of the province (Lausen and Hill 2016). Regional migrants move moderate distances of 100-500 km between summer and winter roosts and can include species such as Little Brown Myotis (Fenton 1969; Fleming and Eby 2003). Resident species breed and hibernate in the same local areas, usually moving less than 50 km between summer and winter roosts. This category may include Big Brown Bat, Townsend's Big-eared Bat and Pallid Bat (Humphrey and Kunz 1976; Fleming and Eby 2003; Nagorsen and Brigham 1993; Cryan 2003).

Migratory bats may move along specific routes instead of migrating in a dispersed pattern (Baerwald and Barclay 2009), which increases the risk of fatalities in localized areas during migratory periods. The majority of bat fatalities reported at North American wind turbines are of migratory species (Arnett et al. 2008; Jacques Whitford 2009; Stantec 2010; Hemmera 2011; Nagorsen and Paterson 2012). Mortality from wind farms is considered to be largely responsible for steep population declines in migratory bats in North America and has led to the assessment and imminent listing of three migratory species as Endangered in Canada (COSEWIC 2023).

Species considered as regional migrants and resident species have also been reported as fatalities at wind facilities, including Little Brown Myotis and Northern Myotis (Endangered, ECCC 2018), Big Brown Bat, and Long-legged Myotis (Kunz et al. 2007b; Arnett et al. 2008; Jacques Whitford 2009; Gruver et al. 2009; Hemmera 2010; Stantec 2010; Jain et al. 2011; Hemmera 2013; Bird Studies Canada et al. 2018).

Table 1 Species of bats in B.C. and whether they have been recorded as fatalities at wind power developments in B.C. as of 2024.

Common name Scientific name	Recorded as fatality in BC?	Select references[1]	Status
Little Brown Myotis *Myotis lucifugus*	Y	a, b, c, d, e	Endangered[2] Blue-listed[3]
Long-legged Myotis *Myotis volans*	Y	c, e	
Long-eared Myotis *Myotis evotis*	No record in B.C. but in the U.S.	f	
Northern Myotis *Myotis septentrionalis*	Y	b, d	Endangered[2] Blue-listed[3]
Eastern Red Bat *Lasiurus borealis*	Y	d, e	Endangered[2]
Hoary Bat *Lasiurus cinereus*	Y	b, d, e	Endangered[2]
Silver-haired Bat *Lasionycteris noctivagans*	Y	a, b, d, e	Endangered[2]
Big Brown Bat *Eptesicus fuscus*	Y	d, e	
Western Small-footed Myotis *Myotis ciliolabrum*	No record		Blue-listed[3]
Californian Myotis *Myotis californicus*	No record		
Fringed Myotis *Myotis thysanodes*	No record		Data deficient[2] Blue-listed[3]
Townsend's Big-eared Bat *Corynorhinus townsendii*	No record		Blue-listed[3]
Pallid Bat *Antrozous pallidus*	No record		Threatened[2] Red-listed[3]
Spotted Bat *Euderma maculatum*	No record		Special Concern[2] Blue-listed[3]
Canyon Bat *Parastrellus hesperus*	No record		Accidental
Mexican Free-tailed Bat *Tadarida brasiliensis*	No record in BC but in the US		Accidental

[1]a-Stantec 2012*a*, b-Stantec 2012*b*, c-Hemmera 2010, d-Hemmera 2011, e-Hemmera 2013, f- Kunz et al. 2007*b*
[2] Committee on the Status of Endangered Wildlife in Canada (COSEWIC)
[3] B.C. listing of species at risk (Red and Blue lists).

Although risk to bats is better understood at onshore (land-based) wind power developments, bats are also at risk of mortality at offshore developments because bats will travel over the ocean during migration or to forage (Ahlén et al. 2007; Cryan and Brown 2007; Millikin 2009b; Sjollema et al. 2014). While B.C. records are lacking, data from other jurisdictions may offer insight into bat movements offshore in B.C. Resident bat species have been reported up to 14 km from the coast in Scandinavia (Ahlén et al. 2009) and on an island up to 8 km from the coast in Maryland. (Johnson et al. 2011). Migratory bats have been reported on islands >30 km from the coast of California (Cryan and Brown 2007) and >100 km from the coast in the North Sea (Boshamer and Bekker 2008). Bat activity, primarily of the migratory species Eastern Red Bat, was also recorded at the most distant detectors (22 km from shore) placed along the coast from New Brunswick through New England (Pelletier et al. 2013; Sjollema et al. 2014). Based on limited information about patterns in bat movement over the ocean, the species likely to be affected at offshore developments less than 10 km from shore are likely similar to those at onshore developments. At offshore developments farther than 10 km from the coast, the migratory bats are the species most likely to be affected, although there is limited information about bat movement between islands and the mainland.

Size of potential impact

The potential overall impact of wind power developments on bat populations is uncertain at this point because information about the size of bat populations in B.C., how far the bats travel, their travel routes and basic information about their life history characteristics is lacking. However, the potential overall impact of wind power developments on bats in B.C. is of concern because:

1. Multiple bat species (including migratory and resident) are at risk of impact. The majority of bat fatalities occur during the autumn migration (Kunz et al. 2007b; Arnett et al. 2008; Baerwald and Barclay 2009; WLRS unpublished data). The limited fatality data available from 2010-2019 for eight wind farms in B.C. indicate that resident bat species, which may be present throughout the active season, are killed in relatively high proportion at some sites and times of years, particularly July and August. In north-eastern B.C., 55% of bat fatalities at one site in 2010 were of resident bat species (Myotis species and Big Brown Bats, Hemmera 2011), while at another, 36% of the fatalities in 2012 were of resident bat species (Hemmera 2013)

2. Bat populations are slow to recover from declines. Females of most species produce one pup per year, although females of the tree bats (Hoary Bat, Silver-haired Bat, Eastern Red Bat) usually have twins. This low reproductive rate means that, as a group, bats are unable to rebound quickly from population impacts and are thus vulnerable to local extirpations

3. Bats have an extended active season in much of B.C. Work with acoustic detectors and mist-netting across southern B.C. has established that some bat species are active throughout the winter (WLRS and B.C. Parks unpublished data). Activity by both migrant and resident bats was recorded at the Bear Mountain project area in north-eastern B.C. at the beginning of the survey season in mid-April (Hemmera 2011), at the Site C project area at the end of March as soon as detectors were deployed (Simpson et al. 2013) and during winter months along the Williston Reservoir (B. Paterson and I,J. Hansen, pers. comm.)

4. Bats use habitat features that could be associated with wind power developments. Research suggests that bats use landscape features (including ridges, riparian areas, coastlines, and wetlands) while migrating and do not move randomly across the landscape (see Serra-Cobo et al. 2000; Baerwald and Barclay 2009). High numbers of bat fatalities at wind power developments on forested ridges in the north-eastern United States (Arnett et al. 2008) indicate that these types of landscape features may be important for bat migration

5. Bats in B.C. are impacted by diverse and cumulative threats (Province of B.C. 2021) in addition to wind power development, including disease, forestry and climate change (B.C. BAT 2024). White-nose syndrome is a devastating disease which has killed millions of hibernating bats (U.S. Fish and Wildlife Service 2012). Pseudogymnoascus destructans, the causal fungus, was detected in B.C. in 2022. It is expected to continue to spread in B.C. from infected areas to the south and east of the province and cause additive population declines to several bat species impacted by wind power developments, two of which are listed as Endangered under the Species at Risk Act (Little Brown and Northern Myotis, ECCC 2018). See Introductory Chapter 1 (section 5.4) for additional information about white-nose syndrome

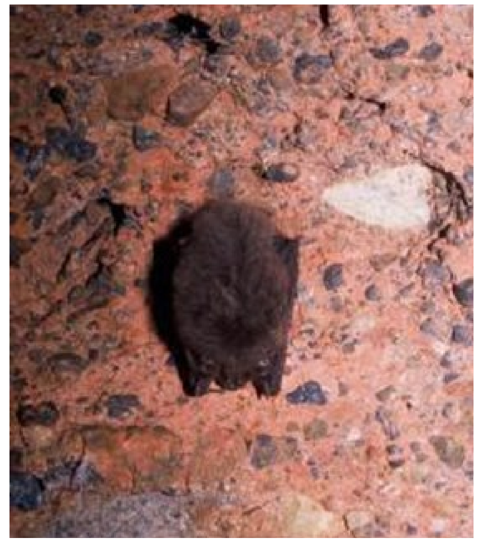
Important types of bat habitat

There are a wide variety of habitat types that may be associated with increased bat activity and that could warrant additional consideration and investigation as high-activity habitat features or areas, such as:

- **River valleys**, along which bats move, particularly during migration (Holloway and Barclay 2000; Furmankiewicz and Kucharska 2009). Crevices in valley walls may also be used for maternity or hibernation roosts. These features, if present in or near the project area, may funnel bat movements, which could result in high levels of bat fatalities
- **Water bodies, wetlands and riparian habitat,** which are used by bats for both foraging and drinking habitat and have higher levels of bat activity (Lunde and Harestad 1986; Brigham et al. 1992; Christy and West 1993; Grindal 1998; Holloway and Barclay 2000)
- **Ridges,** along which bats may travel along forested and non-forested ridge tops and escarpments. The highest reported fatality rates of bats from wind turbines to date is from developments along forested ridges (Arnett et al. 2008)

Bear Mountain wind power development along a ridge. Photo: M. Sarell.

- **Ocean shorelines** are used by foraging bats and may be used as a landmark by migrating bats (Cryan 2003). Bats travel offshore during migration or to forage (Ahlén et al. 2007; Cryan and Brown 2007; review in Pelletier et al. 2013) and are at risk of mortality at offshore wind power developments in the same way as at onshore developments. As with onshore developments, careful collection of acoustic survey data will provide information about areas of higher bat activity
- **Caves, mines, cliffs, rock outcrops, exposed bedrock and talus** are used by bats for roosting, hibernating and foraging. Their relative permanence in the landscape, and the fact that the conditions provided by these roosts remain relatively constant, means that bats may use these features over many years. Bat activity is high around these features at certain times of year (Chapter 3 for BMPs for Cave and Crevice Management and Chapter 2 for BMPs for Mines)
- **Mature and or old forests and trees** provide roosting habitat for many bat species. Bats roost under loose bark, in tree cavities and openings or in foliage (Nagorsen and Brigham 1993; Crampton and Barclay 1998; Barclay and Brigham 2001; Parsons et al. 2003; Willis et al. 2003). Many bat species require a network of roost trees in close proximity to accommodate frequent roost-switching (Willis and Brigham 20024, Olson and Barclay 2013, WLRS unpublished data)



Hibernating Townsend's Big-eared bat. Bat activity levels around hibernacula or maternity colonies can be high at some times of year. Photo: V. Craig.

- **Buildings and bridges** may also provide important day and nighttime summer roosting habitat for bats. Their relatively permanent nature means that bats may use these features for years. Bat activity is high around these features at certain times of year (Chapter 1, Section 4.1.3; Chapter 9)

Other examples of areas associated with higher levels of bat activity include:

- **Migratory routes of bats**. Research in southern Alberta indicates that bats migrate along specific routes rather than dispersing widely across an area (Baerwald and Barclay 2009). Therefore, identifying and avoiding these migratory pathways could reduce mortality. Although specific information on bat migratory routes is not yet available for B.C., potential migratory routes can be assessed based on data from other regions with similar landscapes and by including data on bat activity from nearby areas where available. Data specific to B.C. will be used to identify potential migratory routes as they become available
- **Known or potential hibernacula, maternity colonies, substantial night roosts or swarming sites** such as caves, mines, cliff habitat, buildings and bridges. The presence of these important roost types in the area can be used to identify potential travel routes through the project area

Activities that may impact bats by project phase

The following outlines activities in each phase of development that are the most likely to have impacts on bats and bat habitat. Best Management Practices (BMP) for these activities are outlined in Section 3.

Pre-construction

Pre-construction activities are likely to have little impact on bats or bat habitat. Some activities that might have an impact on bats and bat habitat during the pre-construction phase are the removal of roost trees or rocky bluffs used as roosts to facilitate access, erect meteorological towers and conduct other assessment activities.

Construction

Construction of onshore developments requires the removal or alteration of the habitat within the footprints of the turbines as well as within the areas used for supporting infrastructure, such as roads, substation facilities, meteorological towers, operations centres, transmission lines and temporary construction facilities. As in any resource industry, construction can involve blasting, the removal of trees and rocky outcrops, diversion of water and drainage or disturbance of riparian habitat, ponds or wetlands. All of these activities have the potential to affect bats or bat roosting and or foraging habitat.

The overall effect of construction activities on bats and bat habitat will be influenced by the timing and location of construction.

Post-construction

In the post-construction operational phase, death, either due to blunt force trauma from collision with the turbines or barotrauma, is the major impact on bats once a turbine array is operational. Research indicates fatalities vary by season (Kunz et al. 2007b; Arnett et al. 2008; Baerwald and Barclay 2009), increasing turbine height (Barclay et al. 2007), lower wind speeds (<6 m per second; Arnett et al. 2008; Horn et al. 2008) and periods immediately before or after passage of storm fronts (Arnett et al. 2008).

The reasons why bats do not avoid turbines is still largely unknown and is the subject of ongoing research, including possible attraction to turbines at different scales (Barclay et al. 2007; Kunz et al. 2007b; Horn et al. 2008; Cryan and Barclay 2009, Cryan et al. 2014b, Jonasson et al. 2024). Unfortunately, this means that pre-construction acoustic activity data might not be able to predict fatality levels and therefore not assist in avoidance of fatalities through siting in areas with low activity (Hein et al. 2013). However, areas with confirmed high levels of bat activity and or identified high-value habitats should still be avoided.

Fatality rates may vary across years due to innate yearly variability in bat activity, possible reductions in local bat populations due to ongoing fatalities, and changes in the habitat around the wind facility after the construction activities have ceased and the facility becomes operational. Wind power facilities are expected to be operational over many decades. As the habitat changes both as a result of natural succession, other natural processes such as wildlife, surrounding industrial activities and operational management of the landscape at the wind power development, bat activity and, consequently, fatality rates may change.

Best management practices guidelines

In all project phases, consult the Environmental Mitigation Policy for B.C. and take measures to avoid impact, minimize adverse impacts, restore on-site values and offset residual adverse impacts (B.C. Ministry of Environment 2014 a, b).

Pre-construction (site selection, project design, turbine siting)

Careful site selection is an essential first step to avoid and minimize impacts of wind power development on bats. Site selection should aim to locate projects away from areas of known or suspected high-quality bat habitat or high levels of seasonal bat activity to potentially reduce bat fatalities and the need for additional post-construction and operational mitigation (Government of Alberta 2013).

Pre-construction desktop and baseline survey work should:

- Determine species and species groups present in the study area
- Identify any areas or specific habitat features that might be significant to bats
- Identify seasonal variation in activity levels, times of year when bats are moving through an area (migration periods), as well as variation in bat activity and movement within and between years

Insufficient pre-construction assessments could lead to an ill-informed project location, site design and turbine site placements, which will result in long-term ecological costs and expensive mitigation measures.

Desktop planning and data compilation

- Define the assessment area to include the entire project site plus a buffer that extends for 1 km from the project perimeter (Environment Canada 2007) within which the project is expected to interact with bats and bat habitats. The area may be defined iteratively as new information is gathered (Environmental Assessment Office 2021)
- Identify proposed turbine locations, roads, transmission lines and other supporting infrastructure
- Access existing information in government databases such as:
    - B.C. Conservation Data Centre
    - Wildlife Species Inventory (WSI or SPI) database
    - Wildlife Habitat Features database
    - Environmental Assessment Office project information website (Environmental Assessment Office 2024)

    - Federal Critical Habitat mapping layer
    - Other relevant land designations (for example, Lands Act)
- Consult and or access additional sources as possible and relevant either before or during consultation process. Sources could include First Nations knowledge-holders, communities and or organizations, academic institutions, peer-reviewed literature, local naturalists, grey literature and expert knowledge of biologists about bat populations, hibernacula and the presence of significant bat roosts within the assessment area
- Identify suitable bat habitat (see section 1.4.5 above - caves or mines, cliff faces with suitable attributes, riparian areas, river valleys, wetlands, ridges or forest patches with large numbers of wildlife trees) within the assessment area
    - Obtain existing information on landscape features, biogeoclimatic designations, ecosystem state characteristics and data on the presence of karst formations and historic mining activity
    - For offshore developments, identify features that could provide roosting or foraging habitat for bats (such as islands, lighthouses), as well as shoreline features that could provide habitat for bats or serve as departure sites for bats leaving to forage or migrate over the ocean. For example, peninsulas can form a natural departure point for bats (Pelletier et al. 2013; Sjollema et al. 2014) and wind power developments close to such features might encounter high levels of bat activity, resulting in potential impacts and the need for additional mitigation
- Identify potential cumulative effects of other activities (including other wind power developments, forestry, mining, and so on) within the project area (one km within the project site) when conducting a risk assessment of a potential site (Hegmann et al. 1999; B.C. Ministry of Environment 2024)

Pre-construction surveys

- Develop a comprehensive survey approach to validate desktop analyses, fill critical knowledge gaps and provide additional necessary data. Where the assessment area includes potential high value bat habitat features such as mines, caves, crevices and large tree cavities, identify potential roost areas using acoustic surveys, roost visual inspections or emergence watches (exit counts), thermal criteria, netting and radio-telemetry, or other techniques as needed
- Consider implementing multiple survey methods to address data deficiencies. For example, consider placing acoustic detectors along potential flyways to identify possible migratory pathways (although note that the movement of tree bats may change with the placement of turbines on the landscape, Cryan et al. 2014a)
- Additional information gained by implementing various survey methods can be used to inform placement of turbines and or mitigation options. The utility of various techniques will be project- and site- specific based on recommendations from a QEP
- Surveys should follow relevant protocols in Appendices 1 and 2

- Survey data should inform the timing of and location of construction activities and inform potential mitigation approaches during post-construction
- It is not clear whether pre-construction bat activity data can be used to predict post-construction fatality rates at onshore developments (Hein et al. 2013). As such, two years of pre-construction acoustic monitoring are no longer required. However, pre-construction acoustic activity monitoring can be beneficial to identify important areas for additional acoustic or other surveys, provide information on optimal timing windows for activities, potentially indicate the presence of migratory pathways, flyways or potential roost locations, and inform decisions about mitigation options, including spatial buffers and construction timing windows
- For offshore developments, carcass searches are not possible, and pre-construction surveys should include two years of acoustic surveys. Baseline sampling design is challenging because of the difficulty of installing acoustic detectors across the development area. Placing acoustic detectors on nearby structures at sea or on offshore islands or collecting acoustic data by boat surveys may provide an indication of bat activity in the area. Radar surveys may be used to detect potential migratory flight behaviour in the vicinity of the project area. Although birds and bats cannot be distinguished easily in these surveys, these surveys could contribute to both bird and bat mitigation measures. Consider recent advances in remote-sensing technologies and proposed methods for assessing fatalities before developing a pre- and post-construction monitoring plan to assess bat presence and impacts (Lagerveld et al. 2020, SEER 2022)
- Additional information on specific bat habitat features (such as caves and cliffs) can be found in other BMP chapters and, for roost tree identification, the Wildlife Habitat Features Guide (B.C. Ministry of Environment and Climate Change Strategy 2019)

Incorporating mitigations

- Review the pre-construction desktop assessment and survey data to identify environmental concerns and higher risk areas for bats
- Avoid higher risk locations as a proactive measure to reduce potential fatalities post-construction, as prescribed by the Environmental Mitigation Policy (B.C. Ministry of Environment, 2014a)
- Avoid placing turbine strings or arrays adjacent to potential migratory routes or obvious flyways (such as along a cliff edge)
- Locate turbines away from (and minimize the creation of) well-delineated edges in the landscape, such as forest cutlines. Edge habitat creates foraging and commuting habitat for bats and may serve as a navigational aid, resulting in higher bat activity in these areas (Grindal and Brigham 1999; Verboom and Spoelstra 1999)
- Incorporate setbacks and spatial buffers in planning to minimize impacts to roosts, foraging areas and potential movement pathways. Buffer size will vary according to the landscape, matrix habitat, size and type of roost and the type of development and can be decided based on input from an experienced QEP. The following are minimum recommendations by feature type:

    - Summer roosts for crevice and or cavity roosting bats (which could be found in mature and old stands with suitable habitat, rocky bluffs) – buffer by a distance of at least 120-500 m between a turbine and suspected or confirmed bat summer roosts (Lausen et al. 2010; OMNR 2011, Voigt et al. 2024). There are significant challenges in identification of possible or confirmed summer roosts for foliage-roosting bats due to our lack of understanding of selected roost characteristics (Lausen et al 2022); however, buffering forest suitable for cavity and or crevice roosters will likely also benefit foliage-roosting species
    - For road construction, plan roads where possible to retain large healthy trees and wildlife trees in patches of radius at least 1.5-2 tree lengths (B.C. Ministry of Environment and Climate Change Strategy 2019)
    - Wetlands, riparian areas, other foraging areas – buffer by at least 500 m (Lausen et al. 2010, Voigt et al. 2024)
    - Hibernacula – buffer by 1 km (Lausen et al. 2010, B.C. Ministry of Environment 2016b)
- Consider the relationship between turbine height and species-specific flight heights (if known) and fatality rates and if use of a particular turbine height may contribute to achieving conservation goals (Anderson et al. 2022)

Construction

- In general, avoid clearing forests and removing potential wildlife or roost trees (particularly large live or dead trees with cavities, cracks, and or loose bark) in the following timing windows, to avoid direct mortality of bats in roosts:
    - 1 June through 1 September for maternity roosts
    - 1 October through 30 April where hibernacula in trees are suspected (southern regions)
- In general, if working near bat habitat such as caves, mines or cliffs and crevices, follow practices for timing windows and spatial setbacks outlined in the Bats and Mines BMP (B.C. Ministry of Environment 2016) and Bats and Caves BMP (B.C. Ministry of Environment 2016). Avoid disturbances in these timing windows:
    - 1 June to 1 September 1 for maternity roosts
    - 1 October to 30 April for hibernacula
- **Note:** Timing windows for work around summer roosts and hibernacula can be adjusted to reflect local conditions based on recommendations from a QEP
- If work is to occur within specified avoidance periods, assess the habitat for use by bats and develop a specific mitigation plan to reduce impacts to features that are, or are suspected to be, used by bats or to bats themselves. Ensure that there is proper drainage around turbines so as not to create wet areas or pooled water that might increase insect populations and attract bats

- Clear an area of low-lying vegetation and debris at the base of each turbine, measuring at least 50 m in radius or half the diameter of the peak rotor height, whichever is greater. This will increase the efficiency of post-construction fatality surveys and minimize the attraction of debris piles to small mammals, which could scavenge bat carcasses or attract other wildlife (scavengers or raptors) to the area
- Consider extending pre-construction surveys and data collection during construction to further understand pre-operational bat activity at the site

Post-construction

Bats generally migrate when wind speeds are low (Cryan and Brown 2007). By altering the wind speed at which rotors begin turning, or by altering the blade angles so that rotors stay relatively motionless at low wind speeds, bat mortality can be substantially reduced (Baerwald et al. 2009; Arnett et al. 2010; Arnett et al. 2013b). Most studies indicate that curtailment of rotor speed can reduce bat fatalities significantly, generally by 50-89% (Baerwald et al. 2009; Arnett et al. 2010; Arnett et al. 2011; review in Arnett et al. 2013b, meta-analysis in Adams et al 2021). As of 2024, operational curtailment at peak times of bat mortality, and preventing blades from spinning when not generating, are considered essential mitigation procedures to minimize bat fatalities.

Target fatality thresholds for B.C.

Target fatality thresholds are set at 75% reduction of the 2016 thresholds in the B.C. Ministry of Environment 2016 BMPs for Bats and Wild Power Development. Additional mitigation efforts are recommended if monitoring results for a three-year rolling average exceed any of the following:

- >= 2 Hoary Bat mortalities per facility per year (priority Species at Risk)
- >= 3 bats (uncorrected) at any one turbine in a single year (problem turbine)
- >= the greater of 1.75 bats per turbine per year or 0.58 bats per MW per year (calculated, corrected; average take) or
- 87 bats total per facility per yr (calculated, corrected; total take)

For context, historically, three of eight windfarms in B.C. operating with no curtailment reported corrected per-turbine fatality rates below these thresholds.

The arrival and impacts of white-nose syndrome and or additional information on the decline of migratory bat species may also require modification of these thresholds.

Recommended mitigation measures

To reduce bat fatalities immediately upon commencement of operations, precautionary curtailment is recommended for all turbines in Year 1 of operation:

- Slow or stop turbine blades from turning (usually by feathering) at wind speeds below the recommended cut-in speed:
    - During the entire active season of bats (NASBR 2024). NOTE: The active season varies across the province, and monitoring data can inform this locally after Year

1 of acoustic monitoring at an operational facility. For example, in the South Okanagan, bats are active from March through mid-November; in the Peace, activity is from mid-April through early November; and,

- From 30 minutes before sunset to 30 minutes after sunrise during the active season

- Curtail operation of turbines at wind speeds using either of the following strategies:
    a. A basic strategy of curtailment at or below 6 m per second, measured at hub height:
        - Between 15 July and 15 October at a minimum, to cover peak migration and fatality periods (WLRS unpublished data, Bird Studies Canada et al. 2018, NASBR 2024). At this time there are insufficient data to provide regional timing windows
        - From 30 minutes before sunset to 30 minutes after sunrise
        - Monitor yearly; after three years assess effectiveness of mitigation efforts and if needed, implement adaptive management, in partnership with the research consortium and regulatory agencies (Figure 1)
    b. Implementation and testing of effectiveness of smart curtailment, such as a modified curtailment regime based on local conditions, algorithm-based curtailment, or other smart-curtailment system (for example, linking curtailment to real-time bat activity (Hayes et al. 2019, 2022, Gottlieb et al. 2024))
        - Monitor yearly and adjust curtailment adaptively each year to ensure the rolling 3-year average mortality is below the recommended thresholds in partnership with the research consortium and regulatory agencies (Figure 2)

The initial seasonal-and wind-speed-specific precautionary basic curtailment mitigation practice will ideally become tailored to each development as site-specific data are gathered. Data from post-construction monitoring can be used by the proponent, regulatory body, government agencies and research consortium to inform adaptive management and develop adjusted nightly and seasonal curtailment schedules that reflect local levels of post-construction bat activity. Because of large amount of uncertainty around bat movement patterns in BC, even under the basic curtailment scenario, it is recommended that monitoring results be reviewed yearly to determine if bat conservation could be improved through modifications to the curtailment schedule.

Adjustments to the monitoring schedules and curtailment strategies should be approved by the appropriate regulatory agency with input from government biologists. Proposed changes should be supported by results from acoustic and fatality monitoring and environmental data to inform adjustment of wind speed, dates or nightly timing of curtailment or add temperature or other environmental variables as considerations (Pettit and O'Keefe 2017, Squires et al. 2021, NASBR 2024).

Alternative mitigations that could be considered in Years 2+ may include:

- Altering the amount of time that rotor operation is curtailed based on local fatality and bat activity data, and recommendations from a QEP with specific training in bat ecology

- Researching additional variables to support fine-tuning curtailment periods. Linking curtailment to wind speed, barometric pressure and moon illumination to provide greater precision in identifying periods when bat activity may be higher (Weller and Baldwin 2011) and shorten the period during which rotor speed is curtailed

Wind power developments are encouraged to partner and participate in development and testing of new technologies to reduce impacts to bats and birds and improve monitoring approaches as well as support research efforts to address data gaps (Section 5).

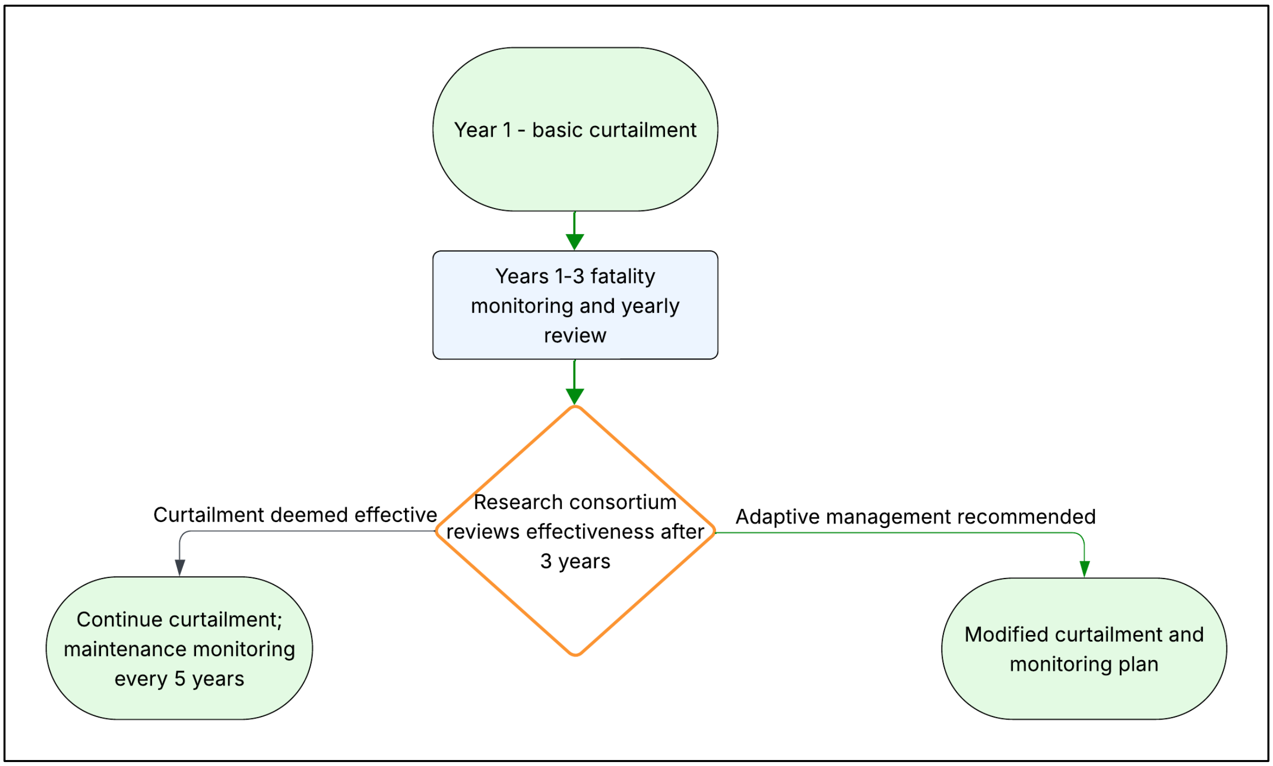


Figure 1. Basic curtailment (strategy ‘a’) mitigation and monitoring decision chart for wind power developments in B.C.

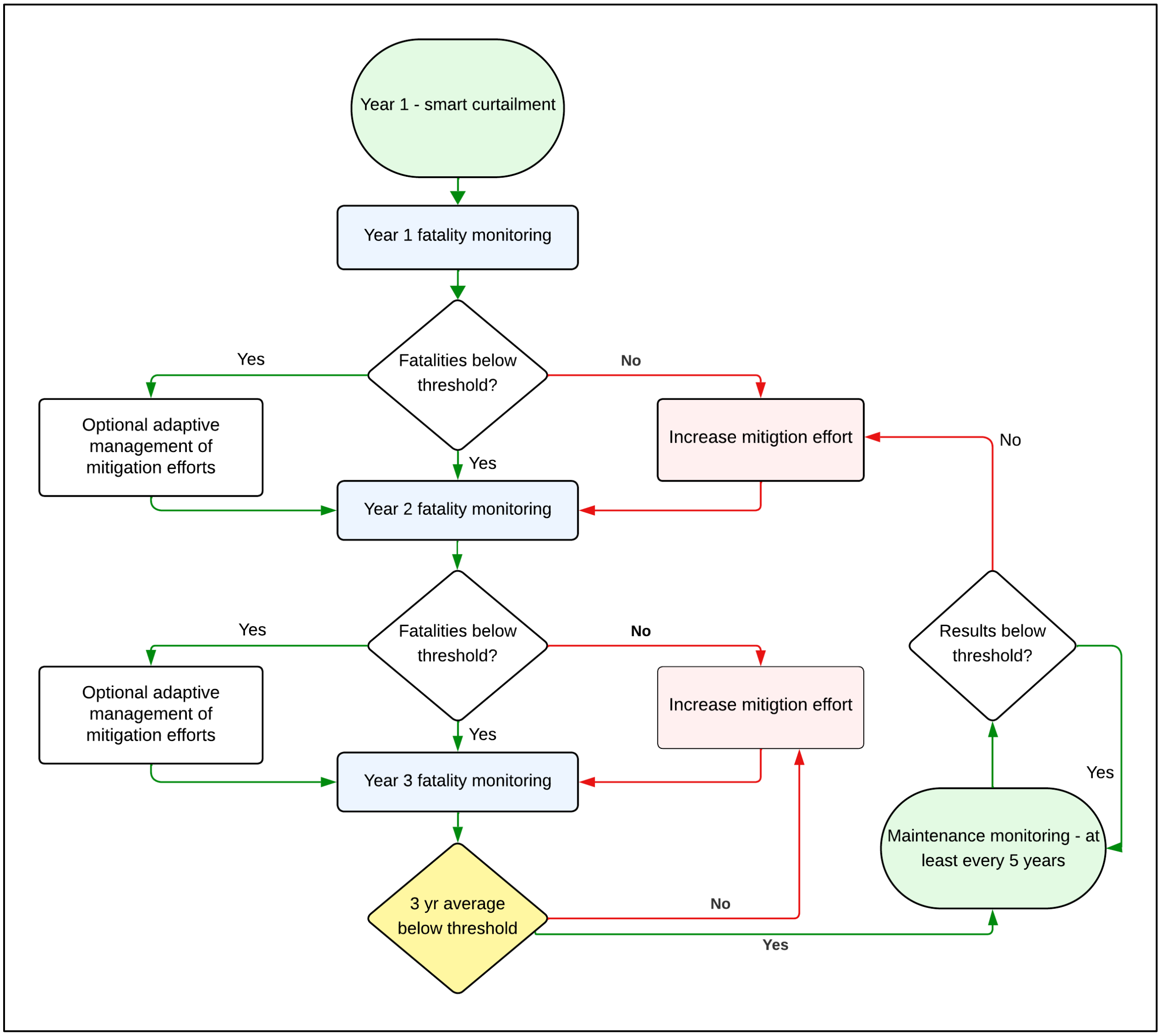


Figure 2. Smart curtailment (strategy 'b') mitigation and monitoring decision chart for wind power developments in B.C.

Post-construction monitoring

Post-construction monitoring is recommended to understand the timing of bat activity post-construction, identify the dates of highest risk to bats at a site-specific level, estimate the number of bat fatalities at a wind power development project, to determine the effectiveness of mitigation and support adaptive management. Acoustic monitoring and fatality searches should be conducted, including repeated searcher efficiency trials and carcass removal trials to address biases inherent in bat fatality surveys (Kerns and Kerlinger 2004; Huso 2010; Warren-Hicks et al. 2013). The use of canines is suggested to support fatality surveys in habitats with a visibility class greater than 1 or where human searchers are unable to meet the suggested 60% efficiency target (see Appendix 2, Bat fatality (carcass) searches).

Outcomes from post-construction monitoring are to include the following:

- Uncorrected bat fatality rate, carcass removal and scavenger rate and searcher efficiency rates
- Estimated adjusted mortality rates per turbine per year and per MW for the total survey year
- Adjusted mortality estimates using the GenEst estimator (Dalthorp et al. 2018, Turber et al 2022, Ravache et al 2024). Proponents may build a substantial case for use of another estimator, acknowledging many estimators exist and each has biases and may be more suitable for a particular study design, (Huso 2010; Korner-Nievergelt et al. 2011; Strickland et al. 2011; Bernardino et al. 2013; Warren- Hicks et al. 2013; Huso and Dalthorp 2014, Dalthorp et al. 2018).
- Examination of patterns in fatalities:
- by species or species group, sex and over time (month)
- across turbines to identify if there are problem turbines or if mortalities are evenly distributed among turbines
- by distance and direction from the turbine
- Examination of correlations between fatality rates and bat activity levels, meteorological conditions, turbine placement and surrounding habitat
- Data submission (summarized acoustic data, raw data on uncorrected fatality counts, results of scavenger trails and searcher efficiency) and reports submitted to WSI to enable other estimator calculations and future meta-analysis as outlined in Section 4 Reporting

In general, for onshore developments:

- Conduct a minimum of three years of post-construction acoustic surveys to identify local patterns of seasonal activity and or to inform operational mitigation such as changing cut-in speeds or adjusting timing of operational curtailment to coincide with timing of local pulses of bat activity
- The acoustic monitoring season may be modified in Years 2+ if acoustic data from previous years indicate a shorter active season in the region
- Conduct a minimum of three years of post-construction bat fatality surveys, searcher efficiency trials and carcass removal trials (Figure 1). Report on all fatalities and data as outlined in Section 4 Reporting
- Survey for bat fatalities twice weekly throughout the active season for bats, from 15 March through 15 October
- The fatality survey season in Years 2+ can be modified if data from Year 1 indicate that fatalities occur only during a much shorter season, such as the migration period
- The frequency of fatality searches in Years 2+ may be altered if supported by carcass persistence data from previous years

- Changes to operations after Year 1 or in subsequent years should be approved by regulators and should involve a revised monitoring plan to assess effectiveness of mitigations over multiple years
- Fatality monitoring results should be calculated as a rolling three-year average. Failure of the three-year average to be below provincial thresholds (3.3.1) should lead to increased mitigation and continued monitoring efforts until a sub-threshold three-year average is reached
- After completion of a three-year monitoring cycle, a reduced fatality monitoring schedule of one year of monitoring (fatality surveys or other data-supported approach) every five years is recommended. Failure to achieve provincial thresholds should lead to increased mitigation and continued monitoring efforts until a sub-threshold three-year average is reached
- Surveys should follow protocols in Appendix 2

Assessing the impact of wind power developments on bats is difficult at offshore developments because it is not possible to conduct post-construction carcass surveys. For offshore developments:

- Continued monitoring of activity levels and meteorological conditions can provide information about potential levels of bat fatalities (Brabant et al 2021)
- Until a robust method of assessing bat fatalities at offshore developments is devised, implement the precautionary curtailment measures recommended in Section 3.3.2 and apply additional measures if any bat activity and weather conditions, such as an approaching storm front, suggest that there may be a temporarily elevated risk to bats

Conservation offsets and alternative compensation

Regulatory bodies acknowledge that mortality of bats, especially listed Species at Risk bats, at windfarms is likely impossible to prevent entirely, even with efforts to avoid and minimize impacts through siting and seasonal curtailment at low wind speeds. Under B.C.'s Environmental Mitigation Policy it is necessary, therefore, to take measures to offset residual adverse impacts that remain or are predicted to remain after all reasonable mitigation measures are applied (B.C. Ministry of Environment 2014 a, b). If a facility is employing what the regulator identifies as reasonable mitigations, the regulator may determine that offsets are required to counteract, or make up for, the residual impact.

Potential offset and compensation measures are those that can promote bat conservation and build resilience in bat populations or contribute to reducing future impacts of wind power projects on bat populations. Suggestions include but are not limited to: supporting research efforts to improve siting and design to improve efficiency of windfarms without increasing risk of killing bats, and contributing to research to address data gaps both on- and off-site (Section 5). Contributions to research could include supporting long-term monitoring efforts to increase understanding of bat population trends and movement patterns (North American Bat Monitoring Program and local BatHubs; purchase and operation of MOTUS towers etc.).

Reporting

Reporting results of all acoustic and fatality monitoring data is essential to increase our understanding of the scope and timing of impacts of wind power development on bats and to improve future mitigation efforts.

Data submission

- Submit all survey and incidental mortality data and associated summary reports yearly to B.C. Wildlife Species Inventory (WSI) database (create one WSI project per wind power development and attach data and reports yearly) as well as submitting reports to the regulatory agency requiring this information
- Submissions should include data from acoustic monitoring (summarized), mortality, searcher efficiency and scavenger surveys, and any additional surveys (roost, capture, radio-telemetry and radar surveys)
- Templates for WSI submission are available from the WLRS Bat Conservation Coordinator or at Wildlife Data Submission Templates
- Submit analyzed acoustic data to the North American Bat Monitoring Program

Project reporting

Detailed reporting requirements will be identified by the responsible regulatory agency. Consider the following guidelines.

- Data from one survey year should be analyzed and reported prior to beginning the next year's survey season. Optimally, reporting would occur by December 15, within two months of completing the survey season (October 15), particularly in cases where alteration of mitigation efforts is proposed, to allow time to fully develop the mitigation techniques and sampling protocol to be used for the following season
- Clearly describe objectives, provide a rationale for surveys conducted, summarize survey dates and the survey methodology (providing sufficient detail that the study protocols and survey effort can be replicated if necessary), details of analyses used, summaries of data collected and results for each survey type employed
- Ensure surveys with zero results are reported (emergence counts at suspect roosts, unproductive capture nights, nights with no bats detected, periods with no fatalities)
- Include observations of bat behaviour or activity levels that could inform mitigation options
- Report meteorological data collected, including wind speed, wind direction, temperature, precipitation, barometric pressure and moon phase
- For all acoustic and fatality surveys, report results and relate findings to meteorological conditions. Analyses should be species- or species group-specific
- In the conclusions, provide recommendations for future work and options for adaptive management of potential impacts on bats (proposing alternative mitigations, data-informed regional timing windows for curtailment)

- Report the results of any mitigation activity and its effectiveness in reducing bat mortality rates

The following outlines suggested types of information to include in reporting for each project phase in addition to reporting required by the regulatory agency.

Pre-construction (site selection and turbine siting)

Reporting should include:

- Summary of desktop planning and baseline data compilation
- Summary of pre-construction surveys (acoustic activity, capture work)
- Identification of potential bat habitat (with supporting mapping)
- Identification of higher risk areas to bats in the project and supporting justification
- Information on how potential effects to bats were avoided (project site selection, turbine type and location etc.)
- Information about how bat habitat and bat activity data were used to minimize impact to bats

Construction

- Report all planned and incidental activities that had the potential to affect bats or bat habitat
- Provide information about any measures taken to prevent or mitigate potential negative effects of the development or construction on bats and bat habitat, and provide the rationale for the measures taken

Post-construction

- Report the specifications of the wind power development including number of turbines, turbine make, turbine tower height, rotor length, overall turbine height, the capacity (rated MW) per turbine as well as the capacity for the entire project
- Provide complete information on all post-construction surveys (i.e., acoustics, fatalities, searcher efficiency and scavenger trials), including:
- survey design (number of turbines searched and their location, dates of the survey season, dates of all completed surveys, including those with no bats or bat activity)
- rationale for each component of the survey design (how the number of turbines searched was determined, how the number of sampling nights was determined, proportion of area searched)
- survey and analysis methodology, (including fatality estimator used), providing sufficient detail such that the study protocols can be replicated if necessary
- outcomes of surveys, summarizing the data submitted in Section 4.1

Bat carcasses

- From Nov 1-May 31, submit all dead bats immediately to the B.C. Wildlife Health Program for WNS surveillance. All submissions must be labelled with date collected, location, and submitters name
- For species occurring outside their expected range, contact the B.C. Bat Conservation Coordinator to arrange tissue collection, storage, and or submission
- Retain carcasses for searcher efficiency and carcass removal trials

Information needs to improve adaptive management

This section identifies knowledge gaps and information needed to better understand bat interactions with turbines as well as ways to better mitigate potential negative effects. Proponents are encouraged to collaborate with researchers whenever possible to develop and run statistically rigorous studies.

Reporting data according to guidelines in Section 4 is an important way proponents can help address knowledge gaps. Meta-analyses and assessment of cumulative effects (Province of B.C. 2021) will rely on the data collected and submitted (section 4) as more wind power developments become operational. Collaboration and data-sharing will result in greater local specificity and effectiveness of mitigation options.

Key knowledge gaps at present include:

1. Species impacted by windfarms and seasonality of impacts. Data submission from new windfarms will address this knowledge gap and improve mitigation recommendations
2. Information on bat migratory behaviour in B.C., including timing of migration by region, existence of migratory routes if any, and behaviour during migration
3. Locations of significant summer and winter roosts (hibernacula) in B.C.
4. The impact of bat fatalities at B.C. wind power developments on provincial bat populations. Genetic and modelling work is encouraged (Vonhof and Russell 2015)
5. Understanding the age, size and sex structure of the fatalities to assess impact on population growth rate or model rates of potential population decline. Data collected to date are insufficient to conduct robust analyses
6. Potential impacts of expansion of wind industry in conjunction with other threats such arrival of white-nose syndrome (cumulative effects)
7. The relationship between pre-construction bat activity levels and post-construction fatalities, and how this may vary with species (migratory versus resident bat species), acoustic detector set-up, turbine height, season, weather, and other covariates

8. The relationship between post-construction bat fatalities and bat activity levels as indicated by acoustic, radar, or thermal camera surveys (Smallwood and Bell 2020)

9. Flight height of bats during different seasons, which could be addressed through thermal or radar imaging and used to inform mitigations, such as appropriate safe space between the ground and the lowest reach of turbine blades

10. Methods of assessing and reducing bat fatality rates at offshore developments, such as linking to activity levels or use of thermal infrared cameras (Kunz et al. 2007a; Cryan et al. 2014a, Solick and Newman 2021). Oregon State University and the Pacific Marine Energy Centre are leaders in offshore wind power development technology in the Pacific region

11. Understanding how bats perceive wind turbines and why they are killed in such large numbers. This is an active area of research that could lead to improved mitigation options or deterrents that consider spatial scale of attraction (Ahlén et al. 2007; Kunz et al. 2007; Cryan and Brown 2007; Baerwald et al. 2008; Cryan 2008; Baerwald et al. 2009; Cryan and Barclay 2009, Arnett et al. 2010; Rollins et al. 2012; Arnett and Baerwald 2013; Cryan et al. 2014a, Jonasson et al. 2024)

12. Effectiveness and economic viability of proposed mitigations, including deterrents, to minimize bat fatalities. Field testing of mitigation options and modelling of benefits to bats and cost to industry is required at a local or regional scale (e.g. Adams et al. 2021, Maclaurin et al. 2022, Hayes et al. 2023)

Collaboration and co-ordination between industry, academics, regulatory agencies and bat biologists is essential to address these knowledge gaps and decrease impacts of wind power development on bats while supporting expansion of this important alternative energy source.

Glossary

This glossary includes technical terms used in or relevant to this chapter of the Best Management Practices for bats series.

Acoustic survey or Echolocation survey: A method of detecting bats using an ultrasonic bat detector to detect bat echolocation calls. Detectors may be hand-held (‘active surveys’) or connected to an electronic system (‘passive surveys’) for long periods of recording independent of human observation.

Active acoustic surveys: An acoustic survey (see ‘acoustic survey’) of bat activity where detectors are manually directed toward and follow a bat and are turned on and off as required. May be used with or without an accompanying recording system; however, use of a recording system during active acoustic surveys is recommended.

Adaptive management: A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form— ‘active’ adaptive management—employs management programs that are designed to experimentally compare selected policies or practices by evaluating alternative hypotheses about the system being managed (MOF 2008).

Barotrauma: Tissue damage caused to air-containing structures (lungs in the case of bats) caused by rapid air pressure changes, such as in blade tip vortices near moving wind energy turbine blades.

Bat Detector: Any device used to render the ultrasonic calls of a bat audible to the human ear (Resources Inventory Standards Committee 2022).

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 Resources Information Standards Committee 2003).

Clutter: An object or surface (including grass, trees, other bats, rocks, buildings) as perceived by a bat; the degree of spatial complexity in the environment (O'Keefe et al. 2014).

Curtailment: Deliberate reduction of power production due to energy supply and demand or operational constraints

Cut-in speed: The wind speed at which turbine blades begin to rotate to generate power.

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

Echolocation: An orientation system based on generating sounds and listening to their returning echoes to locate obstacles and prey (Nagorsen and Brigham 1993).

Ephemeral roost (synonym for short-duration roost): A bat roost in a feature where the characteristics important to bats (microclimate, access, security) may change quickly and or unpredictably. For example, an area under sloughing tree bark.

Feathering: Adjusting the angle of turbine blades so no force is generated and blades do not rotate in the wind.

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 (B.C. Ministry of Environment, Lands and Parks 1998).

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; such actions are prescribed by regulations or rules (Dunster and Dunster 1996).

Hibernaculum: A site where one or more bats hibernate in winter (pl. Hibernacula). A specific hibernaculum may be used by bats for only part of the winter and 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).

Higher risk areas for bats: Areas where the number of bat passes per night >10x the median for that development, season, or region (calculated after one year of data collection at the development and or based on regional data where available), or >1 migratory bat pass per night as identified through acoustic surveys (Government of Alberta 2013); areas with habitat features more likely to be associated with bat activity, such as river valleys; water bodies, wetlands and riparian habitat; ridges; ocean shorelines; caves, mines, cliffs, rock outcrops, exposed bedrock and talus; forests and trees; buildings and bridges; pathways of potential bat movement, such as migratory routes or foraging pathways; areas where the presence of a significant roost has been identified; and areas where higher elevation landforms would increase the relative height of one or more turbines above that of the other turbines.

Impact assessment: A study of the potential future effects of resource development on other resources and on social, economic and or environmental conditions (MOF 2008).

Long-duration roost (synonym for permanent roost): A roost that is available for bat use over many years and has suitable characteristics (microclimate, access, security) that remain stable over time. Examples of permanent roosts include caves, cliffs, mines, bridges, buildings and large hollow trees of a slow-decaying species such as Western redcedar (*Thuja plicata*). Examples of roosts that would not be considered permanent roosts are exfoliating bark, woodpecker cavities and cracks in the boles of non-cedar trees.

Manufacturer's cut-in speed: The minimum wind-speed at which a turbine is built to operate for power generation.

Maternity colony: An aggregation of females in spring, summer or fall. The colony may include pregnant females (which 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 primarily within a single maternity roost feature (building, cave), or a group of females roosting singly or in small groups in close proximity and maintaining a long-term social relationship, adhering to the fission-fusion model (Kerth et al. 2011; such as in crevices within a cliff or boulder field, in a forest stand under sloughing bark of trees). A roost used by such a colony is called a maternity roost.

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

Mitigation: A 'mitigation measure' means a tangible conservation action taken to avoid, minimize, restore on-site, or offset impacts on environmental values and associated components, resulting from a project or activity. (Environmental Assessment Office 2013).

Monitoring: Repeated, systematic measurements done with a specific purpose in mind. 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 (Quayle 2003).

Nacelle: The part of the wind turbine on top of the tower that houses the controlling electronics and machinery of the turbine, including the gear box, drive shaft and blade controls.

Nursery colony: A type of maternity colony containing mainly nursing adults with young (summer) or an aggregation of mainly volant pups (late summer or early fall). A roost used by such a colony is called a nursery roost.

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.

Offshore wind power development: one built in the ocean

Onshore wind power development: one built on land.

Passive acoustic surveys: An acoustic survey (see 'acoustic survey') of bat activity where detectors and recording equipment are deployed at fixed points and programmed to turn on and off on a set schedule.

Permanent roost (synonym for long-duration roost): A roost that is available for bat use over many years and has suitable characteristics (microclimate, access, security) that remain stable over time. Examples of permanent roosts include caves, cliffs, mines, bridges, buildings and large hollow trees of a slow-decaying species such as Western redcedar (*Thuja plicata*). Examples of roosts that would not be considered permanent roosts are exfoliating bark, woodpecker cavities and cracks in the boles of non-cedar trees.

Project area: The project area is the current project site plus a 1 km area around the site, following guidelines by Environment Canada-Canadian Wildlife Service (2007) on the size of a wind power development, which is the number of turbines proposed for the current project as well as the number of turbines within 1 km of the current project site.

Project site: The development site included in the wind facility.

Reporting: The process of effectively communicating the results of monitoring and their potential implications to a target audience (Quayle 2003).

Resident bat species: Species that move relatively short distances between summer and winter habitat compared to migratory species, which travel long distances (>1000 km).

Riparian Area: Riparian areas are three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems. They extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem and along the water course at a variable width (Ilhardt et al. 2000).

Roost: A daytime retreat or night-time resting place.

Short-duration roost (synonym for ephemeral roost): A bat roost in a feature where the characteristics important to bats (microclimate, access, security) may change quickly and or unpredictably. For example, an area under sloughing tree bark.

Significant bat roost:

i. Any hibernaculum or swarming site
ii. A roost used by a nursery or maternity colony of a Red or Blue-listed species (any number of individuals) or a nursery roost used by more than four females of other species (can include mixed species groups)
iii. Any permanent-type (cave, mine, cliff, rock outcrop, talus, building, bridge) regularly used day roost used by a male or a non-reproductive female of a Red or Blue-listed species, or >10 males, non-reproductive females, or juveniles of other species (can include mixed species groups)
iv. Any permanent-type regularly used night roost used by a Red or Blue-listed species or >10 bats of other species (can include mixed species groups);
v. Any regularly used roost of a species listed under Schedule 1 of SARA (any number of individuals) or
vi. Any roost deemed significant by an experienced bat biologist or QEP

Standard: Quantifiable and measurable thresholds that are typically defined in law or regulation and 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, nor does it imply 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).

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).

Wildlife Tree: A tree or group of trees that provides wildlife habitat and assists in the conservation of stand-level biodiversity (MOF 2008). A wildlife tree is any standing live or dead tree with special characteristics that provide valuable habitat for conservation or enhancement of wildlife. These trees have characteristics such as large size (diameter and height) for site, condition, age and decay stage; evidence of use; valuable species types; and relative scarcity. They serve as critical habitat (for denning, shelter, roosting, and foraging) for a wide variety of organisms such as vertebrates, insects, mosses, and lichens.

Additional information

- The Bats and Wind Energy Cooperative was formed by Bat Conservation International, the U.S. Fish and Wildlife Service, the American Wind Energy Association, and the National Renewable Energy Laboratory of the U.S. Department of Energy. These agencies co-operate to develop solutions to minimize or prevent mortality of bats at wind power developments. The site has numerous research papers available for download
- The B.C. Bat Action Team (B.C. BAT) is composed of bat researchers and government personnel and has regular meetings that may include discussion of wind energy
- The Alberta Bat Action Team (ABAT) has a wind energy working team and is linked to university researchers examining impacts of wind farms on bat populations in Alberta
- The North American Bat Monitoring Program and the NNW NABatHub accept acoustic monitoring data from wind farm projects
- In the U.S., the National Renewable Energy Lab (NREL) and the ECO Wind program support research into protecting wildlife and ensuring sustainable wind power development
- Copies of all legislation for the province of B.C. are available online
- B.C. Ministry of Environment Guidelines and Best Management Practices for environmental stewardship
- The BatAmp Bat Acoustic Monitoring Portal provides open access to contributed acoustic data, to visualize bat occurrence by species over time
- B.C. Species and Ecosystems Explorer has information on all species of bats in the province

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Appendix 1 - Pre-construction survey methodology

The guidance below is in addition to that outlined in the B.C. Resources Information Standards document 'Inventory Methods for Bats' (B.C. 2022).

Roost surveys

- Use existing Wildlife Habitat Features guidance to identify potential roost trees, rock roosts, or hibernacula in the project area (B.C. Ministry of Environment and Climate Change Strategy 2019)
- To confirm if a feature is a roost, consider using exit counts, visual roost searches, or placing an acoustic detector at entrances or inside the feature. Due to seasonal variation in use, as well as roost-switching by bats, acoustic monitoring throughout the suspected period of use may be a more efficient method of identifying bat use than internal surveys or visual exit counts
- Survey potential roosts a minimum of once per season, acknowledging that an absence of bat activity or sign does not necessarily mean that bats do not use the feature
- Search for guano inside and at exits of potential roosts. Collect pellets for species identification through genetics
- Use may be confirmed by placing a plastic sheet at the entrance to the roost or below hard-to-inspect cracks and crevices. Failure to detect guano does not mean that bats do not use the feature
- All surveys of potential hibernacula should use the most up-to-date decontamination protocols
- Work in and around mines, caves, bridges and buildings should follow the BMPs developed for those resources (see B.C. BMPs for Bats: Chapters 2, 3 and 9, B.C. Community Bat Program resources, B.C. Wildlife Health Program 2016, 2024)
- Collect data on all roosts surveyed, including location, type of roost (for example, tree, cave, mine, cliff), and general attributes (size, location and entrance characteristics) data
- For occupied roosts, collect data on type of use (for example, maternity, swarming site, hibernacula), species identity and number of bats using the roost

The presence of bat guano inside and/or at the exits of potential roosts can provide evidence of bat use. These may be obvious large piles of guano (Photo: V. Craig) or individual pellets on vegetation or walls directly under roost exits/entrances (Photo inset: C. Olson).

- Additional information such as location of bat use within the feature and additional attribute data such as temperature and microclimate profiles may also be useful depending on the objectives of the study
- For roost exit counts, record number of bats that emerge, time of emergence, and location and type of emergence portals
- For acoustic detector surveys of roosts, analyze data as per guidelines for acoustic surveys – see Appendix 2.
- Report survey and analysis results as outlined in section 4

Capture (mist-netting) surveys

- Capture (mist-netting) survey of bats is an optional technique that may be used to understand the composition of the bat community, including species (present or not-detected), sex, reproductive status and age. It also can be used to assess bat species' use of foraging or commuting sites and can be used in conjunction with radio-telemetry to better understand bat use of the area or to identify the location of a suspected significant roost in the area. Any bat capture and handling requires a permit under the B.C. Wildlife Act and must be conducted by experienced bat biologists. All personnel handling bats must have pre-exposure rabies vaccinations before mist-netting
- Follow the B.C. RISC standards for bat inventories (B.C. Ministry of Environment, Lands and Parks Resources Inventory Branch, 2022) for any capture program
- Report survey and analysis results as outlined in section 4
- Tabulate the number of bats captured by categories such as species, sex and age. For each category, summarize data by number captured per net-night or per hour where appropriate

Radio-telemetry

- Radio-tracking of captured bats can be used to answer questions about habitat use by bats in the area, such as the location of roosts. The use of radio-telemetry should balance the potential stress to the bat with the benefit of discovering a significant roost to inform a risk assessment of the site, placement of turbines and or potential mitigation
- Where roosts are discovered through radio-telemetry, collect data on roost characteristics and report bat capture data and telemetry results to WSI as outlined in section 4

Radar

Placement of radar installations is an optional technique that can be used to collect additional information on bird and bat movements through the area. Radar has been used to identify movements of birds at wind power developments, sometimes in combination with thermal imaging or acoustic monitoring (Mabee et al. 2005; Ahlèn et al. 2007; review in Kunz et al. 2007b; Cryan et al. 2014a), although research to date indicates that detection of passage of birds and bats is not closely correlated with fatalities (U.S. Fish and Wildlife Service 2012).

Radar has a greater range in the ability to detect bats than acoustic detectors; however, with current technology, it is difficult to accurately distinguish bats from small birds. The erratic flight path of foraging bats can be distinguished from the flight of birds. However, commuting bats have straighter flight paths and may not be distinguished from birds, which may lead to underestimation of the number of migratory bats in the area (Mabee et al. 2006; Kunz et al. 2007b).

Research on the use of radar at wind power developments is continuing, and as technology improves, radar may become a useful tool to monitor bat activity, particularly in situations where the lack of infrastructure means there are no or limited options for installation of acoustic detectors, such as at offshore developments (Pelletier et al. 2013). Combining radar with acoustic detectors or visual surveys may increase the certainty in identification of bats. At the current level of technology, radar is not recommended for routine assessment of bat populations, but where it is used for assessment of bird movement, the opportunity exists to look for evidence of bat movements.

Below is an overview of radar use in pre-construction or post-construction surveys.

- The timing of data collection will be influenced by the objectives of the work. For example, gathering information on migratory pathways will be conducted during periods of peak expected movements
- Collect data from 30 minutes before sunset to 30 minutes after sunrise
- Include both the horizontal and vertical planes to be able to identify bat flights within the proposed rotor-swept area
- Consider pairing radar with acoustic recordings to enhance ability to identify bats and bat species groups on radar
- Radar may be used in addition to acoustic detectors during boat surveys for assessing bat use of offshore areas (Ahlén et al. 2009). Where acoustic data are recorded along with radar data, follow the acoustic surveys guidelines for data collection and reporting as outlined above
- Save radar survey data onto digital media so that the flight path data can be subsequently reviewed and quality checked
- Record information on bat behaviour, including flight direction and changes in direction, and information on foraging areas
- Infrared detectors can be used in conjunction with radar to gather additional information about bat behaviour around turbines, as well as fatalities (Kunz et al. 2007a; Horn et al. 2008; Cryan et al. 2014a). At this time the costs of this technique are high; however, as the technique and equipment are further developed, the costs of including infrared detectors are expected to decrease (Kunz et al. 2007a)
- Investigate data for evidence of potential migratory pathways, flyways or foraging areas that should be avoided by wind power developments
- Correlate flight altitude and bat behaviour to meteorological data to identify patterns that could inform placement or management of wind turbines

- To identify any potential biases, analyses should compare acoustic and radar data when both data are available. Both data have their idiosyncratic biases. The maximum distance of acoustic bat detection will be different than the range of radar, and migratory bats may not echolocate often (although see Ahlèn et al. 2009); hence migratory bats may be underreported by acoustic surveys. The inability to identify species and the reduced ability to distinguish migrating birds from bats creates biases in radar data

Appendix 2 – Post-construction monitoring methodology

The guidance below is in addition to that outlined in the B.C. Resources Information Standards document 'Inventory Methods for Bats' (B.C. 2022).

Acoustic surveys

Post-construction passive acoustic surveys are recommended at all proposed wind project areas, including onshore and offshore developments. Pre-construction acoustic surveys are recommended at offshore developments. Surveys should be designed based on the type of development, size of project area, landscape and survey objectives, and they should be informed by recommendations from a QEP.

Post-construction acoustic surveys can be used for specific purposes such as to:

- Determine whether bat activity at the site varies in timing, species (groups) or location once turbines are installed and the site is altered (survey methods must match pre-construction monitoring methods to make the data comparable)
- Collect bat activity data at heights reflecting airspaces possibly used by bats, for example, 10 m and nacelle-height (Bat Conservation Trust 2009). Some types of detectors have add-ons designed to improve performance when placed in a nacelle (for example, Batcorder, ecoObs 2010). Placement of detectors in the nacelle should be undertaken carefully to ensure that the turbine is not interfering with the recordings (see Hydro Tasmania 2012). A trial period may be necessary to determine the correct placement of the microphone and to determine whether useful data are being collected
- Detect patterns in bat activity post-construction to inform designing of potential mitigation options, such as by collecting real-time activity data
- Collect complementary data if radar is used in post- construction monitoring to assist in differentiating bat from bird activity
- Confirm use of a suspected roost

Generally,

- Survey from 1 March through 31 October. Consider year-round sampling to identify patterns of bat activity at the site outside this window
- Collect concurrent bat activity and meteorological data to identify correlations

- Survey a minimum 30 minutes before sunset until 30 minutes after sunrise nightly throughout the survey period. Surveys may start earlier in the evening in fall and winter as there are anecdotal reports that bats fly earlier in the evening in the fall and winter
- Use and clearly document standard methodology for analyzing data to species or species groups, such as at least one auto-identification program plus manual identification (Loeb et al. 2015)
- Additional data collection may be recommended if: data are assessed as inadequate in duration or quality due to high variability in bat activity; there is presence of species at risk or the potential presence of significant bat habitats, such as roosts, hibernacula or migratory pathways; or if there are significant mechanical or logistical issues with data collection

Additional protocols include:

1. Survey season

    - Onshore: 1 March through 31 October at a minimum. Consider year-round sampling to better identify patterns of bat activity at the site, as some bats may be active year-round (Burles et al. 2014; de Freitas 2023, K. Safford, unpublished data, C. Lausen, unpublished data, WLRS unpublished data)
    - Offshore developments: 15 March through 31 May, and 1 August through 15 October
    - Detection of bat activity within one week of starting or stopping sampling could indicate that bats are active at the site earlier or later than the period sampled. In those cases, consider extending the survey period to capture the entire period of bat activity at the site

2. Number of detectors

    - For onshore, the number of detectors used will vary depending on the size of the turbine array and the complexity of the habitat, but the number should be sufficient to survey bat activity across the project area
    - For all developments, effort should be made to monitor bat activity along any likely migratory routes, flyways (Lausen et al. 2010) or potential significant habitat features
    - A minimum of five detector stations (could have multiple detectors per station at different heights) should typically be deployed in the project area (Lausen et al. 2010) to capture bat activity across the site. With five detectors, placement would be at all four cardinal points and one in the centre. Ideally, for large developments, deploy >five detector stations around the area. To identify potential migratory flyways of bats, additional detectors at varying heights may be required
    - For offshore developments, the number of detectors will vary depending on the size and orientation of the turbine array, the difficulty in installation, the type of sampling and the distance offshore, but the number should be sufficient to survey bat activity across the project area. Acoustic detectors on boats can supplement data from detectors placed on structures

3. Height

    - Detectors should monitor activity from surface level to at least the middle of the rotor-swept area. To accomplish this, install two detectors or two microphones (using long cable) per Met tower or other tower or structure at heights representative of the proposed turbines. Bat species detected can vary with detector height (Kunz et al. 2007a; Collins and Jones 2009; Weller and Baldwin 2011; Staton and Poulton 2012). Therefore, placing detectors at multiple heights increases the probability of fully sampling the bat species present as well as species that may fly through the rotor-swept area
    - Co-ordinate setup for acoustic surveys with Met tower installation at the site. A pulley system to allow maintenance and data download from bat detectors can be installed during the construction of the tower more easily than trying to retrofit a system. Where Met towers are not present across the development area, consider installing temporary towers (preferred) or mounting detectors high in trees to collect bat activity data at sufficient height. Wherever possible, microphone orientation, accessories such as reflector plates, and detector sensitivity or gain settings should be used to maximize detection volumes that include the proposed height of the rotor-swept area
    - At detector stations, deploy at least one detector at minimum 30 m height on each Met (meteorological) tower, turbine or on temporary towers erected at a site. Position the detector so that the microphone monitors bat activity within the proposed rotor-swept zone (which may be >30 m, and could be up to 110 m)
    - A second detector or microphone may be placed at a minimum 1.5 m height on the Met tower
    - In addition to detectors at turbines, place ground-based acoustic detectors (at least 1.5 m above ground and away from other reflective surfaces, such as tree trunks) around areas of potentially high bat activity or areas where significant roost or hibernacula or foraging habitat could be present (for example, around cliff faces, caves, wetlands)
    - For offshore developments, the focus may be primarily on migrating species. Follow the above guidelines for sampling on structures as much as possible, and focus on having detectors as high as possible. On boats, the detectors should be set up on masts or as high as possible. Other detectors placed on buoys should be set up to sample as much project area, as high as possible (Tetra Tech 2012). Use of reflector plates for directional microphones may be necessary to increase sampling volume without compromising microphone longevity (rain or snow could damage microphones over the long term if they are oriented vertically)

4. Sampling design

    - Sample across the project area, and have detectors placed so that the perimeter of the array is monitored in all four directions (north, south, east, west) in addition to the centre of the project area (Lausen et al. 2010)
    - Sample areas suspected to support high levels of bat activity

- Sample random reference sites, such as Met towers, to provide baseline bat activity data for the site
- All detectors within each stratum at a site should sample at a similar height from the ground or surface to provide comparable data across the project area
- Position the detectors to maximize the likelihood of differentiating species (i.e., low clutter recordings where bats are flying in the open, minimize recording of echoes)
- Recognize that even sites at high elevations may support bat populations (Epcor Power Development [BC] Limited Partnership 2009)
- Consider locating additional detectors in high suitability bat habitat within the 1 km buffer around the proposed development site (the total project area) to provide context to project site-specific data on bat activity and habitat use patterns
- When sampling at offshore sites, focus on identifying potential bat migratory routes or flyways
- Active acoustic surveys, where detectors are manually directed toward and follow a bat, may be useful in some projects, such as targeted surveys for offshore developments (Tetra Tech 2012); however, they may not be as efficient or cost-effective as passive surveys (Coleman et al. 2014). Active acoustic surveys should occur from 30 minutes before sunset to at least midnight or 1 a.m. depending on bat activity. An experienced QEP should determine the survey protocol for active surveys based on the study objectives, the latitude of the project area and season of study

5. Detectors

- Use detectors capable of recording continuously and autonomously from 30 minutes before sunset to 30 minutes after sunrise and for multiple nights before data need to be downloaded
- Check data quality regularly so that technological problems can be resolved in a timely manner. Avoid long periods of unmonitored recording as detector malfunction may not be detected until too late in the season. If this occurs, monitoring may need to be repeated the following year, thus delaying project implementation or construction. A remote data download system is recommended where site access is difficult. Consider building redundancy in the number of detectors deployed. The relative expense of detectors may be small compared to problems arising from insufficient data
- Detectors should record sufficient information about bat calls for the calls to be identified to species or to species-groups for species that cannot be distinguished based on acoustic characteristics alone
- Weather-proof bat detectors as appropriate. Detectors used in the marine environment (such as those on buoys), may require special weatherizing (Tetra Tech 2012)
- If waterproofing is required, detector microphones should have a rain hat system or sound reflector as appropriate for the brand of detector used (Kunz et al. 2007a). Note that the waterproofing system may influence the data recorded (Britzke et al. 2010) and may

decrease the sensitivity of the microphones, resulting in apparently lower recorded bat activity. All reporting should include a clear description of any weatherproofing used

- All detectors should be of the same type, installed similarly (for example, if sound reflectors are necessary for some of the detectors, all of the detector stations at a development should use them) and have the same settings (full spectrum) or be calibrated (zero-crossing) to provide comparable data
- Note that directional and omnidirectional microphones require different placement to optimize recording quality and species identification
- To facilitate comparison across studies, a complete description of the detector set-up should be included in all reporting (Adams et al. 2012)

6. Other data

- Collect meteorological data to complement the acoustic data. Bat activity at a site can vary widely depending on season, weather, temperature and moon phase (Arnett et al. 2008; Baerwald and Barclay 2011; Johnson et al. 2011); therefore, collect information on wind speed, wind direction, temperature, precipitation and barometric pressure. Meteorological data can be collected by Met towers, data loggers or portable weather stations

7. Additional guidance for offshore developments

- Deploy detectors (passive automated monitoring) along the coastline in areas suspected to be departure point for bats, such as peninsulas (Pelletier et al. 2013; Sjollema et al. 2014), on offshore islands or any nearby structure where bat activity might be monitored (including lighthouses, bridges, navigational towers or buoys; Tetra Tech 2012)
- Acoustic monitoring transects can be done from boats in the area of the proposed wind facility (Ahlén et al. 2007, 2009; Sjollema et al. 2014) to complement data collected with detectors placed on permanent structures
- Boat surveys can occur opportunistically in conjunction with other research or work activities. For example, Sjollema et al. (2014) attached acoustic detectors to research vessels working on other projects, to a tourist fishing boat, as well as a dedicated bat acoustic sampling boat. To be cost-effective, boat surveys can combine nocturnal bird surveys and radar surveys. Although opportunistic, sampling can provide useful information on species (groups) present and areas and timing of activity
- During the survey season for offshore (Section 3.1.2.1), boat-based surveys may be conducted up to twice weekly during the migratory periods (15 March through 31 May and 1 August through 15 October; Rodrigues et al. 2008) and once every two weeks during the period from 1 June to 31 July in years 1 and 2. In Years 3+, conduct surveys during migratory periods and periods of additional bat activity identified in Years 1 and 2. Intensity and duration of surveys will need to be site-specific based on known information on bat activity in the area, data from nearby land-based and fixed structure continuous passive acoustic surveys, and expert knowledge

- Given that the major cost of boat surveys is the boat time, consider building redundancy in the sampling design by using two detectors per boat to minimize data loss due to malfunctions. This may also enable collection of data on the port and starboard sides of the vessel (Sjollema et al. 2014) if the microphones are directional
- Locate microphones well above sea level (such as mounted on the top of a mast). When possible, use either an omnidirectional microphone or, if only directional microphones are available, use two microphones facing opposite directions
- Mount detectors as high as possible on the boat to increase sampling volume
- Conduct sampling on nights with lower wind speeds (<6 m per second, which is when bats are most active), clear conditions (no rain or fog) and a suitable temperature (>5 0C) to get the most accurate data on potential peaks of bat activity
- Establish parallel transects designed to sample the project area
- Keep a log of GPS coordinates for each survey
- Establish a boat survey speed of approximately 10 knots (~18.5 km per hr) over the transect area (ESS Group Inc. 2012). If boats with loud engines are being used, consider stopping at regular intervals, cutting the engine and recording and or listening for bats that might otherwise not approach the boat close enough to be detected
- Survey time within areas should be constant (constant effort per unit area) so that data collected on intensity of bat activity is comparable across areas, days, weather conditions and other covariates that could potentially affect bat activity
- Recognize that boat noise may create interference with the detectors. Review preliminary acoustic data to determine if the boat should be stopped during sampling or the detector set-up changed to minimize interference

8. Analysis of acoustic data

- Analyze acoustic data to identify species or species groups. Minimally, Hoary Bats and Eastern Red Bats should be distinguished from other species groups (Big Brown Bats-Silver-haired Bats and Myotis species). In some cases, Big Brown and Silver-haired bats also can be distinguished and the Myotis group can be refined to either species or subgroups of one or two species within the genus
- Summarize activity by species or species group to identify the total, average and median number of bat passes per detector night. To facilitate comparison across studies, also present activity data as average number of bat passes per hour expressed per species or species group
- Investigate how activity by species or species group varies across seasons, by bat detector height or placement, and across the project area
- Compare activity among bat detectors to identify patterns in movement (i.e., potential migratory routes or flyways) and high levels of activity that could indicate the presence of a foraging area, travel route, maternity colony, hibernaculum or other significant roost nearby

- Interpret acoustic data in conjunction with meteorological data collected at the site. Summarize data by season and relate bat activity to environmental and or meteorological factors to identify patterns in bat activity that could inform turbine management or mitigation. At a minimum, investigate variation in bat activity in relation to moon phase, barometric pressure, wind speed and temperature
- Interpret bat activity data and information on habitat distribution from the development area within a greater regional context. To do so, include bat activity data and or habitat data from other projects in the region where available
- Report summarized acoustic analysis results to B.C. Wildlife Species Inventory database and NABat as outlined in section 4

Bat fatality (carcass) surveys

1. Planning fatality surveys

- Conduct post-construction, operational period fatality surveys for a minimum of three years post-construction
- Changes to mitigation measures require additional monitoring to assess effectiveness. For example, additional effort may be required if problem areas are identified and adaptive management undertaken or if acoustic monitoring and fatality results support a change to the timing and or duration of the initial late-summer to fall curtailment period
- Develop a survey protocol that clearly outlines how the post-construction surveys will be conducted and the data analyzed to inform adaptive mitigation measures if necessary
- Identify how areas of higher risk identified in pre-construction surveys will be monitored
- Surveys should identify the date, location, number, species and sex of bats killed, allowing the derivation of the number of bat fatalities per turbine per year and bat fatalities per rated MW per year
- When developing data forms, consult the B.C. Species and Ecosystems at Risk data collection templates for bat mortalities at wind farms to identify the minimum required data variables to collect for each search
- Identify what will be done with carcasses of species at risk or those for which little information is known in B.C. (for example, Eastern Red Bat). In the WNS surveillance period (Nov 1 – May 31), submit all carcasses to the Wildlife Health Program for testing. Outside of this period, submit carcasses of interest to either the UBC Beatty Museum or the Royal BC Museum
- A provincial Wildlife Act permit is required to possess live or dead bats. Apply through FrontCounterBC
- All searchers should have pre-exposure rabies vaccinations and use gloves while handling bats
- Use of carcass-sniffing dogs is suggested to improve searcher efficiency in low visibility habitats (Class 2+, Table 1). Data comparing human searcher efficiency in low visibility

habitat versus high visibility habitat indicate that small carcasses are 4-5 times more likely to be discovered in high visibility areas (Hemmera 2009; Smallwood 2013). Use of dogs in vegetated areas will significantly improve fatality estimation and lower search costs (del Valle et al. 2020, Smallwood et al. 2020)

2. Search effort

   - Monitor at least 33% of all installed turbines, with a minimum of 10 turbines monitored. Always round up to the next whole number (for example, for an array of 55 turbines, monitor 19-28 turbines)
   - For wind facilities with 10 or fewer turbines in the project area (small developments), monitor all of the turbines (Environment Canada 2007; U.S. Fish and Wildlife Service 2012)
   - For wind facilities with 11 or more turbines in the project area (medium, large and very large facilities; Environment Canada 2007), the number of turbines monitored should be sufficient to provide a good estimate of fatalities at the site. This may require balancing the number of turbines searched with the size of the search area
   - Note that survey effort sufficient to ensure that fatality rates are being accurately estimated may require monitoring a greater number of turbines than the minimum number indicated above, for example, in cases with ‘problem’ turbines requiring mitigation or in areas of higher risk identified during pre-construction surveys. Proponents should consider monitoring more than the minimum number of turbines, particularly in Year 1, to assist in identifying patterns in mortality at the site and to guide future sampling. At some B.C. developments, 50-100% of turbines have been searched (Hemmera 2010, 2011; Stantec 2012a, b; Hemmera 2013)
   - In some cases, particularly areas with low visibility habitat, sampling more of the turbines within a smaller search area (but keeping some larger reference areas) may be a suitable approach

3. Selecting turbines to search

   - Classify the habitat at each turbine according to the amount and height of ground cover. Suggested visibility classes include (from OMNR 2011):

Table 2. Visibility classes for carcass searches (OMNR 2011)

% Vegetation cover	Vegetation height	Visibility class
≥ 90% bare ground	≤ 15 cm tall	Class 1 (Easy)
≥ 25% bare ground	≤ 15 cm tall	Class 2 (Moderate)
≤ 25% bare ground	≤ 25% is > 15 cm tall	Class 3 (Difficult)
Little or no bare ground	≥ 25% is >15 cm tall	Class 4 (Very difficult)

- Select turbines that encompass the variety of habitat types at the site and the geographic extent of the area. However, turbines with a large proportion of heavy ground cover (i.e., class 4 visibility class) should be excluded from the candidate turbines unless the area can be cleared
- Turbines should be selected in a manner that facilitates statistical analysis (stratified sampling). For example, select a random sample of turbines at the site, stratified by habitat type and encompassing the entire array (S, N, E, W and centre) for sampling. Include any turbines located near higher risk areas for bats as identified during pre-construction sampling
- Ensure that it is safe to search the area around the selected turbines
- After Year 1, information on fatality rates, bat activity levels and any changes to mitigation efforts should be considered in selection of the turbines to be monitored in Year 2. Note that adequately defining fatality rates may require sampling more than the minimum number of turbines
- Each year, examine the acoustic survey data and fatality data to identify potential problem turbines at the site that have not yet been monitored and consider including them in the sample
- Where mitigation has been applied to a subset of problem turbines, include those in the sample

4. Frequency of searches

- Search selected turbine every three or four days for a total of twice weekly during the search period (Ravache et al. 2024). Smallwood (2013), in a review of projects across North America, reported that, on average, 68% of bat carcasses remained at day 3; therefore, searches every three days will likely be adequate for the majority of developments. Smallwood (2020) also found that the reporting of small bat species (such as Little Brown Myotis) increased with more frequent carcass intervals
- The search window should reflect scavenger rates for the site and season and be shorter than the average carcass removal time (Strickland et al. 2011). The search interval should be shorter where average carcass removal time by scavengers is shorter than three days (for example, where average carcass removal time is 2.25 days, shorten the search interval to every two days)

5. General protocol for carcass searches

- Begin carcass searches as early in the day as possible to minimize scavenger effects
- Record the start time and end time of each turbine search
- Record environmental variables for each search, including temperature, wind speed, wind direction, precipitation, cloud cover % and any significant weather occurring prior to the search
- Vary the order in which turbines are searched

- The optimal search area may vary by project. The radius of the search area should be determined by the height of the tower and rotor, i.e. the size of the rotor-swept area. The search area should be a circle of a minimum radius of 50 m or half the maximum rotor height, whichever is greater (for example, a turbine with a maximum rotor height of 120 m will have a search radius of 60 m). The majority of bat fatalities are discovered within this area (Kerns et al. 2005). Recognize that the minimum 50 m radius search area may underestimate fatality rates of bats (Bird Studies Canada et al. 2018). Hull and Muir (2010), Smallwood (2013), and Zimmerling et al. (2013) also suggested that many carcasses of bats and or birds fall farther than 50 m from the turbine. To ensure that the search radius is sufficient, ensure that the search area is proportional to the maximum rotor height, as indicated above, and consider having even larger expanded search areas at a portion of the searched turbines to determine whether bats are falling outside the search area
- Surveyors look for bat carcasses along transects or in subplots within each search area. Transects should be no more than 5 m wide, resulting in surveyors searching approximately 2.5 m on each side of the transect. Warren-Hicks et al. (2013) indicated that transects 6-8 m wide are too far apart for detecting bats. Where ground cover is dense (for example, vegetation, coarse woody debris), reduce the distance between transects or size of subplots to increase accuracy in carcass searches
- Where the entire search area cannot be searched due to logistical or safety concerns, adjust the fatality estimate to account for the proportion of area searched. Using a simple proportion of area searched might provide a biased estimate because bat fatalities typically are not evenly distributed in the area around the turbine. For a more accurate estimate, use information on patterns in fatalities with distance and direction from the turbine to estimate fatalities in the unsearched area (Huso and Dalthorp 2014)

6. Recording mortalities and incidental finds

- Collect information about the location of each carcass, including a GPS coordinate as well as the distance and direction from the tower, recorded using a rangefinder and compass. Information on the habitat should also be recorded
- Take a picture of each carcass in situ. Record information from each carcass, including: species, sex, life stage (juvenile or adult), sexual condition (reproductive or not), weight (fresh carcass), forearm length and other appropriate measurements for suspected species (such as ear length, tibia length), external signs of trauma, and carcass condition (fresh, minimal decomposition [starting to smell but intact], moderate decomposition, advanced decomposition, complete decomposition or scavenged; OMNR 2011)
- Identify species following a standard key to identify bats in the field, such as Lausen et al. 2022. For species difficult to identify in the hand (e.g. some Myotis species) or rare bats, the entire carcass, or at minimum a tissue sample, should be obtained to enable genetic analysis or examination of skull morphology by an expert
- Collect two wing-tissue samples for genetic testing. Wearing gloves, snip a piece of wing or tail membrane and use scotch tape to stick the small piece of tissue to a cardboard index

card. Air-dry samples. Label samples with date, GPS location, name and or company of the collector, name of the wind power development, the turbine number and the likely species

- After data are recorded, carcasses should be chilled and then frozen as soon as possible. Carcasses should be frozen double-bagged with a copy of the data sheet included in the outside bag
- Plan a strategy of assigning discovered carcasses to various uses, for example, for immediate use in carcass removal or searcher efficiency trials, or freeze for future use in trials or to preserve for research purposes
- Should a bat be found from Nov 1 through May 31, contact the Ministry of Water, Land and Resource Stewardship Bat Conservation Coordinator or the Wildlife Health Program (B.C. Wildlife Health Program 2016)
- Incidental finds of bat carcasses outside of regular search periods may provide additional useful information, such as hotspots of mortality, and data collection on these incidental carcasses should follow the same protocol as that for carcasses discovered during planned monitoring. However, incidental mortality finds may bias fatality estimates if not analyzed properly. There are three ways of adjusting for incidental mortality rates depending on the area where these incidental mortalities are discovered:
    - For incidental finds of carcasses inside the search area at monitored turbines between scheduled surveys, collect data on the carcass and include the fatality in the estimate for that turbine (Smallwood 2013). This may slightly overestimate the fatality rate when adjusted for scavenger rates calculated for the standard three-day search interval because the scavenging rate for shorter periods will be the same or less than that for day 3. To minimize the bias, the carcass fatality could be added to the fatality total for the turbine once independently adjusted for searcher efficiency and the appropriate mean scavenger rate for that sampling period. For example, if the carcass was discovered on day 2 of the schedule instead of day 3, use the scavenger rate for day 2 to adjust the fatality instead of using the three-day scavenger rate
    - For incidental finds of carcasses outside the search area at monitored turbines, collect information on the carcass and the distance and direction from the turbine as below. Use the data in species composition of fatalities and to examine distance that carcasses fall from turbines to provide feedback to the search area size. Add the uncorrected fatality to the adjusted fatality count for the overall estimate of fatality at the development for the year
    - For incidental finds of carcasses at unmonitored turbines, collect information on the carcass as below and add the information to the number of carcasses found (raw count of number killed, species killed, distance from turbine, and so on), but do not include the fatality in the overall fatality estimate for the facility

7. Live bats

- Assess bats found alive but injured:

  - Bats with major physical trauma, such as large lacerations, obvious and especially compound fractures of wings or legs, head or eye damage should be humanely euthanized
  - Bats with less severe injuries should be transported and treated by wildlife rehabilitators and their veterinarian as soon as possible if these resources are available nearby
  - Bats that do not show obvious, severe injuries but are weak and do not fly may only be dehydrated or heat- stressed. They may respond to rehydration and body cooling (see short term care below). However, they may also have internal injuries or suffer from other illnesses, including rabies
- A protocol for short term care for dehydrated bats is detailed in Klug and Baerwald (2010), and the following rehydration protocol is extracted from that and other references:
  - For mild cases of dehydration, oral hydration can be attempted using an eyedropper, small brush or syringe with warm, or at least body temperature, 50% electrolyte solution (Pedialyte) or water
  - Moderate to severely dehydrated bats may not drink. Subcutaneous administration of warm Lactated Ringers solution is a faster and more effective method of rehydration. 1-2 mls can be administered to a small bat (Little Brown) and 3 mls to a larger bat (Big Brown). Subcutaneous fluid administration requires instruction and experience as bats are tiny and delicate animals. Surveyors should be prepared to administer fluids where necessary
- The treated bat should be held and monitored in a warm (not hot) and aerated container (place in a cloth bag within a small box) in a dark, quiet location for up to two hours. A heating pad can be set on low under the holding container to provide warmth depending on the environmental temperature. If heat exhaustion is suspected, keep the bat in a cool location instead. Once the bat appears recovered, it can be maintained in the cloth bag in cool (not freezing) conditions
- If recovered, treated bats should be released the day of discovery. If the bat is a lactating female, release it as soon as possible, preferably in a protected area such as within forested habitat. Other bats should be released as soon as possible after dusk. Any bat that is not releasable that day should be transported to a wildlife rehabilitation facility as soon as possible
- Where necessary, euthanize bats in a humane manner consistent with AVMA guidelines. Recommended protocol involves using a chemical inhalant (isoflurane, halothane). Use the inhalant full strength and keep the bat in a confined space, such as a small, sealed container, until it can be verified that the bat is dead

Searcher efficiency trials

Searcher efficiency trials are necessary to estimate the proportion of bat carcasses that are missed during searches.

1. Develop searcher efficiency estimates for each human or dog searcher, and for each season, to adjust the estimate of the number of bat fatalities at the development according to the proportion of the turbines searched by each searcher, by season and visibility class of the search area

2. Conduct searcher efficiency trials for all searchers (human and dog) at least three times a year (spring, summer and fall). Monthly or continuous trials during the survey season or during periods of peak bat activity are preferred, to get the best estimate of how searcher efficiency changes over time. In areas where the ground cover is dense, or where the vegetation changes rapidly during the month, conduct searcher efficiency trials more often

3. Searcher efficiency trials can be conducted in combination with carcass removal trials

4. Searchers should not know when a trial is occurring as this may bias the search efficiency estimate

5. Obtain genetic samples from all bat carcasses (see protocol above) for archival purposes before using them in searcher or scavenger trials; this is especially important for difficult-to-identify species so that species identification can be verified

6. While setting up the searcher efficiency trails, carcasses should be distributed in various habitats in relative proportion to habitat types or visibility classes at the site

7. Only one or two test carcasses should be placed per turbine to a maximum of 10 carcasses placed across the project site at any one time. Over the survey year, each surveyor should be exposed to at least 20 bat test carcasses and more if possible. Strickland et al. (2011) recommend that surveyors be exposed to 50 test carcasses within each visibility class, each season, to reduce bias

8. Place carcasses within the search area by dropping them from height to mimic carcass position from a turbine

9. Mark the carcasses or collect sufficient data to track them. Options include marking the carcasses in a discreet area to identify them as trial carcasses, pulling a specific tooth or using passive integrated transponder (PIT) tags. The distance and direction from the tower and GOS location should be recorded for each planted carcass

10. Immediately after the trial, check the site for undiscovered test carcasses to ensure that these carcasses were still present and had not been scavenged before the trial

11. After searcher efficiency trials, carcasses can be left in place for scavenger removal trials (see below). If not used in scavenger removal trials, retrieve carcasses to avoid attracting scavengers to the area

12. Use bat carcasses, if possible, during trials. Bat carcasses have a distinctive appearance and cannot be easily substituted. Warren-Hicks et al. (2013) reported that searcher efficiency for bats was only about half that for small birds. Use local bat carcasses if available. Local wildlife

rehabilitation centres or other wind projects within B.C. could be sources of bat carcasses. Note that a permit is required to possess and transport dead bats. Do not exchange bats between regions of B.C. or across provinces because of potential movement of pathogens, such as white-nose syndrome

13. If no bat carcasses are available, carcasses of dark-coloured mice or small rats may be considered. Another option may be small brown birds, such as Japanese Quail (*Coturnix japonica*). Clearly identify in reports whether the searcher efficiency estimates were based on bat or other carcasses

14. Recognize that if alternate species carcasses are used instead of bat carcasses, searcher efficiency for bats might be overestimated and fatality estimates of bats underestimated

15. Because searcher efficiency will likely vary by bat type (large, small, colour), habitat type or visibility class, weather conditions and season, record information on the numbers and types of bats used in the trial, the habitat and environmental conditions in which the trial was conducted, and the number of bats found in each category. Investigate these data to identify patterns in searcher efficiency that can inform future activities

16. High searcher efficiency will reduce bias in the final mortality estimate (Dalthorp et al 2018). Reported searcher efficiencies ranged from 30- 95 % from 2010-2019 (WLRS unpublished data). Aim for searcher efficiency rate of > 60% by

    - ensuring that surveyors are adequately trained
    - excluding low visibility (class 4) areas from search plots
    - improving the visibility of the area by maintaining vegetation in a grass or forb stage, as searcher efficiency declines with increasing vegetation (Arnett et al. 2008; Mathews et al. 2013)
    - using trained dogs if necessary to reach searcher efficiency targets

17. Searcher efficiency can be calculated as: p^ = number observed per number available and calculated overall, by bat categories, season, weather and visibility category. Use searcher efficiency to adjust estimated fatality rates according to the proportion of turbines searched by each searcher, by season and by visibility category

Carcass removal or scavenger trials

1. The removal of bat carcasses by scavengers before the carcasses are discovered by searchers may introduce bias into fatality estimates. Be alert to the possibility of scavengers 'trap-lining' the area and efficiently removing carcasses

2. Conduct carcass removal trials to determine the rate at which carcasses are scavenged from the site, and use the information to adjust the estimate of the number of bat fatalities at the development

3. Use the information on scavenger rates to determine the frequency of carcass surveys

4. Combine carcass removal trials with searcher efficiency trials and or bat fatality searches by leaving carcasses in place and recording their presence or absence over time. This can be done on a continuing basis or by conducting discrete trial periods

5. Obtain genetic samples from difficult-to-identify species that are used in searcher or scavenger trials (see protocol above)

6. Conduct carcass removal trials at least once each season (spring, summer, fall) and preferably monthly during the survey season to identify changes in scavenger activity

7. Include at least 10 bat carcasses per season in carcass removal trials if possible

8. Where possible, use bat instead of bird carcasses during carcass removal trials because small bird carcasses may be scavenged more quickly (Kerns and Kerlinger 2004; Nicholson et al. 2005; Warren-Hicks et al. 2013; although see Smallwood 2013)

9. Use fresh carcasses, if available, during carcass removal trials. Research indicates that fresh carcasses are removed at different rates than previously frozen bat carcasses or older carcasses (Kerns et al. 2005; Smallwood 2010; Stantec 2012b). Results of carcass removal trials using previously frozen carcasses should recognize this limitation

   - If frozen bat carcasses are used, thaw them before beginning the trial

10. Use a variety of species in carcass removal trials to account for size-related differences in scavenging rates

11. Place only a few carcasses at a time (<10 across the entire project site and maximum only one or two per turbine) to avoid drawing scavengers to an area (increasing apparent scavenging rates) or, alternatively, swamping scavengers with too many carcasses (reducing apparent scavenging rates; Smallwood et al. 2010a and b)

12. Wear gloves when handling carcasses to minimize human scent that might alter scavenger rates

13. Place carcasses in various habitat types to determine removal rate by habitat type or visibility

14. Check carcasses daily during carcass removal trials to accurately determine when they disappear

   - Using movement-triggered camera traps can provide information about the exact length of time until a carcass is scavenged as well as the scavenger species at an area

15. Carcasses still present after 14 days should be removed from the site

16. Adjust seasonal bat fatality estimates by seasonal scavenger rates

Analysis of fatality data

1. Estimate bat-specific rates for carcass removal or scavenger rate and searcher efficiency rates. Do not apply rates for birds to bat fatality estimates

2. Calculate proportion of the area searched by season and ground cover

3. Examine searcher efficiency data to look for patterns such as efficiency by bat type (colour, size), weather conditions and habitat type

4. Determine carcass removal or scavenger rate by season and ground cover (visibility) as well as size and colour of carcasses

5. Calculate individual searcher efficiency rates by season and ground cover

6. Estimate mortality rates per turbine per year and per MW by season and ground cover as well as for the total survey year using GenEst. Although many estimators exist and each has biases, (Huso 2010; Korner-Nievergelt et al. 2011; Strickland et al. 2011; Bernardino et al. 2013; Warren- Hicks et al. 2013; Huso and Dalthorp 2014, Dalthorp et al. 2018), GenEst (Dalthorp et al. 2018) is currently widely recommended (Ravache et al 2024). If another estimator is to be used, provide rationale and discuss with regulators

   - Provide sufficient data (raw data on uncorrected fatality counts, results of scavenger trails, and searcher efficiency) to WSI and in the report to enable other estimator calculations and future meta-analysis

7. Examine patterns in fatalities

   - by species or species group, sex, and by season
   - across turbines to identify if there are problem turbines or if mortalities are evenly distributed among turbines
   - by distance and direction from the turbine
   - for correlations between bat activity levels, meteorological conditions, turbine placement, or surrounding habitat and fatality levels

8. Where acoustic data are available earlier or later in the season, determine whether the carcass search season might underestimate the number of fatalities for the year

Appendix 3 - Text description of Figures 1 and 2: Mitigation and monitoring decision charts for wind power developments in B.C.

Strategy a – basic curtailment

1. Year 1 – initiate operations, implementing the basic curtailment approach. Conduct fatality monitoring for 3 years. Review results yearly and after 3 years assess effectiveness with the research consortium and regulatory agencies. Is the mitigation deemed effective by the team?
    a. If yes, continue basic curtailment and proceed to Step 2
    b. If no, develop an adaptive management plan including increased mitigation efforts and a modified monitoring program, in partnership with the research consortium and regulatory agencies
2. Maintenance cycle – maintain mitigation efforts as implemented in previous years. Implement one seasonal fatality monitoring session at least every 5 years to re-evaluate effectiveness

Strategy b – smart curtailment

3. Year 1 – initiate operations, implementing a smart curtailment approach. Conduct fatality monitoring. Are fatalities below thresholds?
    a. If yes, proceed to Year 2 or consider optional adaptive changes of mitigation efforts and proceed to Year 2
    b. If no, increase mitigation effort and proceed to Year 2
4. Year 2 – Conduct fatality monitoring. Are fatalities below thresholds?
    a. If yes, proceed to Year 3 or consider optional adaptive changes of mitigation efforts and proceed to Year 3
    b. If no, increase mitigation effort and proceed to Year 3
5. Year 3 – Conduct fatality monitoring. Is the three-year average of monitoring results below thresholds?
    a. If yes, proceed to Step 4 - Maintenance cycle - maintain mitigation efforts as implemented in previous years to ensure fatality rates remain below thresholds

b. If no, increase mitigation effort and proceed to actions described in Year 3 and continue this loop until the 3-year running average is below threshold before proceeding to Step 4

6. Maintenance cycle – maintain mitigation efforts as implemented in previous years to ensure fatality rates remain below thresholds. Implement one seasonal fatality monitoring session at least every 5 years. Are fatalities below thresholds?

    a. If yes, return to Step 4 – Maintenance cycle. Implementing one seasonal fatality monitoring session at least every 5 years to ensure fatality thresholds are not exceeded

    b. If no, increase mitigation effort and return to actions described beginning in Year 2, following the subsequent steps until the 3-year running average is below fatality thresholds