Wind Energy and Bat Conservation – A Review by the Canadian Wind Energy Association

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On behalf of DNV GL Energy Advisory, it brings us great pleasure to present the final *Wind Energy and Bat Conservation Review*. This document reflects the extensive effort put forth by DNV GL, Natural Resource Solutions, Inc., and the Canadian Wind Energy Association over the last three years to gather and summarize the vast quantity of information available with respect to wind energy and bat conservation in Canada. It serves as the most comprehensive and current resource of its kind, drawing upon an expansive body of research, industry experience, and insights from technological innovators. The comprehensive treatment of subjects including the effectiveness of bat-impact avoidance and minimization measures, wind facility siting considerations, post-construction monitoring, emerging technologies, and potential mitigation options is unsurpassed in current summary documents. To thoroughly address these issues, our team consulted over three hundred published scientific papers and reports, and conducted multiple interviews with academic researchers, technology developers, and wind industry operators. The Review also serves as the only synthesis of current knowledge with a focus on regional issues specific to Canada. It highlights the fact that there is still considerable uncertainty when it comes to addressing the challenges related to wind energy and bat conservation, and much to be learned if we want to effectively address them. Because of this uncertainty, the Review offers a structured adaptive framework for addressing bat conservation issues that takes an iterative approach.

Because of its accessibility and readily navigable, structured format, the Review will be a valuable tool to a wide variety of stakeholders and interested parties. The Review will aid communication and collaboration among the various individuals, organizations and agencies interested in wind energy and bat conservation in Canada by providing a single, credible source of scientific information to help guide decisions and inform long-term strategies. In this way, we can collectively continue to meet Canada's commitment to provide citizens with clean energy and combat the negative impacts of climate change on people, bats and other wildlife. We believe this *Wind Energy and Bat Conservation Review* will serve as an exemplar by which reviews for other regions will be guided and assessed as we continue, on a global scale, to improve our understanding of and strategies for addressing issues related to wind energy and bats.

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EXECUTIVE SUMMARY

The Canadian Wind Energy Association (CanWEA) has developed this Wind Energy and Bat Conservation Review ("Review") to address uncertainties regarding the interactions between wind energy development and bat populations. The Review provides the wind industry, policy makers, and other stakeholders with a scientific and ecological approach to supporting renewable energy production to meet Canada's commitment to provide citizens with clean energy alternatives, while minimizing the potential for impacts to bats. This Review provides a comprehensive and objective summary of the body of scientific and practical knowledge pertaining to bats and wind energy gained over the last several decades, and provides a structured process for incorporating this knowledge into effective strategies.

Wind energy has become the largest source of new electricity generation in Canada over the last decade. Wind energy is a near zero-emission energy source that can help reduce greenhouse gas (GHG) emissions from the electricity sector. At the same time, concern about the potential impacts of wind energy on bats has increased with the rapid pace of wind development across Canada, the United States (U.S.), and Europe. Whereas it is generally recognized that wind energy facilities pose a lower risk to bat population sustainability than other sources of bat mortality, including white-nose syndrome (WNS), environmental contaminants, habitat loss, and the ongoing impacts of climate change, the wind industry recognizes that wind energy facilities can have direct and indirect effects on bats and their habitats, and continues to seek ways to avoid or minimize these impacts.

Regulatory agencies in several Canadian jurisdictions have taken steps to establish guidelines and protocols to minimize potential impacts to bats. Although it is appealing to have standardized approaches to avoidance and minimization, these guidelines are often based on the findings of a limited number of early bat studies in the U.S. or other regions with different ecological conditions. The goal of the Review is to provide current information and an adaptive management approach that incorporates new research and technology into the development of effective strategies to conserve bat populations. Therefore, this Review has the following objectives: 1) facilitate sound policy discussions and flexible mitigation plans across the country, 2) provide avoidance and minimization, and compensation options for varying circumstances, 3) enhance existing information in order to drive science-based policy decisions, and 4) support updates and revisions of provincial and/or federal guidelines pertaining to bats and wind energy. It is anticipated that reference to this Review can better position the wind industry, regulatory agencies, and other stakeholders to make individual project decisions based on the best-available science. This will result in more efficient, targeted bat conservation, will provide the industry with more predictable project costs and expectations, and will allow Canada to continue to expand renewable energy development using sustainable, science-based approaches to project siting and operations.

The Review is organized into chapters that summarize key components of overall development and management. A brief abstract of each chapter is provided in the following paragraphs.

Siting and Development Considerations. The avoidance and minimization of impacts to bats begins at the siting stage of development. Information on bat communities, population numbers, habitat preferences, foraging and breeding behaviours, key habitat features, seasonal trends, and micro-siting considerations can aid in selecting pre-construction strategies for projects. Whereas additional research is needed to better establish the effectiveness of these strategies, the wind energy industry has continued to take a conservative approach with measures such as implementing setbacks and buffers around potential bat use areas. Similarly, the types of biological information noted above can inform efforts to develop science-based siting policies. There are 20 bat species that occur in Canada, and although it is not practicable to avoid siting wind energy facilities near features of importance to all of these species, pre-construction assessments of concentrating features like water bodies and forests can contribute to impact avoidance. Key strategies include siting and micro-siting to avoid important habitat features and designs that avoid the creation of attractant features.

Post-Construction Monitoring and Estimating Impacts to Bats. Post-construction monitoring, most commonly in the form of fatality monitoring, is an important component of impact assessment and adaptive management to minimize impacts of development. Post-construction fatality monitoring for wind energy facilities presents significant challenges due to the competing needs for precision and affordability. Fatality monitoring typically consists of searches for bat fatalities beneath turbines at set intervals. Because bat carcasses may go undetected for a variety of reasons, leaving us with incomplete information or uncertainty regarding the actual number of fatalities,a statistical estimator is used to calculate an estimate of this value based on the number of fatalities detected. There are multiple variables that can significantly affect final fatality estimates and should be considered when developing a post-construction monitoring plan. These variables include sampling protocols and designs, carcass persistence, searcher efficiency, effective sampling of the carcass distribution and the choice of estimator.

Operational Avoidance and Minimization. It is not possible to avoid all impacts to bats during the development of wind energy projects. Measures to avoid and minimize impacts during operations are therefore important tools for effective bat conservation. Avoidance and minimization refers to steps taken to prevent impacts of an activity or to minimize those impacts where it is not practicable to completely avoid them. Operational avoidance and minimization strategies are designed to reduce bat fatalities at operational wind energy facilities, and implementation of these strategies often takes into account a facility’s characteristics (e.g., turbine layout, wind speeds, proximity to bat concentration areas such as bat hibernacula). Operational avoidance can include general measures (e.g., timing restrictions on maintenance activities, avoidance of hibernacula), operational modifications such as turbine curtailment, deployment of risk reduction technologies such as bat deterrents, or a combination of these measures. Flexibility in approach is paramount to the success of these strategies. The early-stage development and testing of most technical measures currently available also offers opportunity for the wind industry to participate in research to assess their effectiveness and identify conditions under which they are most effective.

Compensation and Offsets. When predicted or observed effects on bats cannot be avoided, it may be appropriate to compensate for these effects to reduce or eliminate the potential net impact. The emergence of white-nose syndrome in North America has produced severe impacts to some bat populations in Canada; targeting mitigation of white-nose syndrome is therefore a high priority for bat conservation. Wind energy developers and operators seeking methods to compensate for their much lower effects can perhaps have the greatest impact by working to reduce the impact of white-nose syndrome. Additional compensation options that can return conservation benefits to bats include habitat protection, habitat enhancement, and conservation banking. Some options, such as habitat protection or enhancement and long-term forest management are widely applicable and feasible, whereas others like captive bat programs or reduction of WNS impacts are more limited in scope or practicability. The applicability of a given compensation option and the best path to conservation benefit for a wind farm will likely depend upon the unique circumstances of the facility.

Adaptive Management Framework. The prediction and mitigation of potential impacts is imperfect, and it is therefore important to adaptively manage operations and monitoring activities as new information becomes available. Adaptive management refers to a structured, iterative process by which recurrent decisions are made based on information gained from the results of prior management actions. Adaptive management is most appropriate when there is baseline knowledge to inform predictions about the effects of management actions tied to a decision, but there is scientific uncertainty about those predicted outcomes. In a wind-industry context, adaptive management can occur at the project level, to inform and adjust ongoing management decisions, but perhaps more importantly at a broader scale, wherein information from multiple projects can inform policy, planning, and standard practice over time, reduce uncertainty about wildlife populations potentially at risk, and help improve decisions at new projects. To this end, the industry, in partnership with agencies, has developed a wind energy bird & bat monitoring database that represents the most comprehensive standardized repository of wind-wildlife data in Canada. The Review provides a summary of the mitigation hierarchy commonly applied to wind energy, places this in the context of balancing sustainable energy production and bat conservation, and provides a conceptual structure for organizing and reaching management decisions. The framework provided in this chapter should facilitate discussions among industry, regulatory agencies, and environmental NGOs about the best ways to proceed with individual projects, as well as how to work together to identify best practices that are both effective and practicable. A key benefit to taking an adaptive management approach is that the focus remains on maintaining sustainable bat populations in Canada. The approach thus allows for flexibility, accommodates consideration of a variety of measures and combinations of measures to optimize strategies for individual projects, reduces scientific uncertainty over time, and recognizes the role that clean energy plays in reducing threats from fossil fuel reliance and resultant climate change.

Conclusions. The Review provides an assessment of the efficacy of various mitigation options to avoid, minimize or compensate for wind energy effects on bats, along with monitoring considerations, and an adaptive framework aimed at improving bat conservation efforts across Canada. Key conclusions from this comprehensive assessment are shown in Table ES-1-1; a more detailed summary may be found in Section 7.

Table ES-1-1 Key Review Conclusions

Subject Area	Key Conclusions
Pre-Construction Avoidance	• Little scientific evidence is available concerning the effectiveness of various common siting and pre-construction avoidance measures commonly recommended by regulatory agencies and adopted by the industry, including options for setbacks from preferred habitat and other micro-siting considerations. • Current pre-construction avoidance measures are based on scientific understanding of general ecology and phenology of bat species. • Because pre-construction avoidance measures have the potential to reduce risk to bats and typically cost less than avoidance, minimization, and mitigation measures applied at the operational stage, these options may be considered and applied when practicable.

Table ES-1-1 Key Review Conclusions

Subject Area	Key Conclusions
	• An adaptive management approach by the wind industry and other stakeholders is expected to improve confidence in the effectiveness of some of these measures over time.
Operational Avoidance	• General avoidance measures are typically less costly than operational minimization options and are based on a vast body of bat ecology literature. Further research regarding the effectiveness of these measures is expected to improve avoidance strategies adopted by the wind industry. • Although several operational deterrents are in development and showing some promise of effectiveness, no proven methods are commercially available. • The most promising deterrent technologies to date are acoustic deterrents. Additional technologies under development include texturized coatings and low-level UV lighting. • Using an adaptive management framework will allow industry, regulatory agencies, and academics to work cooperatively to accelerate the identification and commercialization of effective bat deterrent measures.
Operational Minimization	• In general, operational curtailment and feathering has been shown to be effective for reducing bat fatalities, however, the optimal strategy for minimizing impacts to bats is unknown, particularly with respect to the benefits of raising cut-in speeds above 4.5 m/s. • Reported effectiveness estimates from raising cut-in speeds to 4.5 m/s or greater ranged from a 47 to 96% reduction in bat fatalities. Results varied within and among curtailment strategies (e.g., feathering vs. free-wheeling, specific cut-in speed). • Several integrated monitoring-minimization systems are commercially available and could minimize costs by providing more targeted curtailment, however these systems require further independent evaluation. • Emerging monitoring technologies, such as IR and improved species identification systems, are in the early stages of effectiveness testing, but are not yet fully commercialized. The industry and regulatory agencies have the opportunity to cooperatively evaluate the potential for these new monitoring approaches to improve operational minimization strategies and systems. • Through an adaptive management approach, the industry, regulatory agencies, academics and other stakeholders can work cooperatively to identify the thresholds, conditions, and combined methods (e.g., with avoidance measures) that can effectively minimize impacts to bats while maintaining project sustainability. As more is understood about the effectiveness of various minimization measures, monitoring requirements at individual projects are expected to decrease over time.

Table ES-1-1 Key Review Conclusions

Subject Area	Key Conclusions
Fatality Estimation	• Fatality estimation requires appropriate decisions regarding monitoring protocols, search parameters, and statistical estimators. • The most commonly used fatality estimators rely on varied assumptions and are affected differently by variables including search frequency, scavenger trial and searcher efficiency trial methods, and search area. • Flexibility should allow individual projects to identify which monitoring designs and estimators, based on project-specific conditions, are most likely to produce unbiased fatality estimates. • Fatality estimation provides a means of informing the adaptive management process regarding the need for and effectiveness of avoidance and minimization measures.
Compensation and Offsets	• Compensation and offset options may be appropriate in some circumstances. • Options may include habitat protection or enhancement, reducing the impacts of WNS, and/or conservation banks. • These options are generally most effective when they are targeted to specific species. • Compensation and offsets can be considered during all project phases (e.g., Siting, Operations). • Compensation and offsets may be considered as part of an overarching adaptive management strategy aimed at reaching bat conservation goals, and assessment of these measures offers additional opportunities for partnerships and research efforts.
Adaptive Management Framework	• Adaptive Management is an iterative learning process that improves the effectiveness of bat conservation measures over time. • The learning process has high utility for individual wind projects, but is most effective when aimed at broad-scale conservation goals and informed by information from multiple wind energy projects as well as by external research efforts. • The underlying goals of adopting an adaptive management process are to facilitate renewable energy development thus reducing the impacts of climate change, maintain stable populations of bats in Canada, and reduce scientific uncertainty with respect to conservation strategies. • As more is learned, mitigation and monitoring strategies will become more targeted, cost effective, and beneficial to bats. • With a reduction in scientific uncertainty, it is expected that the need for intensive monitoring at individual projects will also be reduced. • As adaptive management implies, there needs to be a willingness by both operators and regulators to implement innovative strategies to maximize reductions in bat fatalities; the framework is most effective when not constrained by “boiler plate” mitigation, which may have limited potential to provide benefits.

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ACRONYMS AND ABBREVIATIONS

AB	Alberta
BC	British Columbia
BCI	Bat Conservation International
BMP	Best Management Practice
BWEC	Bats and Wind Energy Cooperative
CARs	Canadian Aviation Regulations
CEC	California Energy Commission
CDC	Conservation Data Centre
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CP	Carcass Persistence
CWHC	Canadian Wildlife Health Cooperative
DOE	Department of Energy
EERE	Energy Efficiency and Renewable Energy
GHG	Greenhouse Gas
IEA	International Energy Agency
IR	Infrared
ITP	Incidental Take Permit
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources
MB	Manitoba
MET	Meteorological
MNRF	Ministry of Natural Resources and Forestry
MW	Megawatt
MWh	Megawatt Hours
NB	New Brunswick
NBC	National Bat Committee
NGO	Non-governmental Organization
NL	Newfoundland and Labrador
NRSI	Natural Resources Solutions, Inc.
NS	Nova Scotia
NT	Northwest Territories
NU	Nunavut
ON	Ontario
ONWR	Ottawa National Wildlife Refuge
PE	Prince Edward Island
QC	Quebec
RPM	Rotations per Minute
RSA	Rotor-swept Area
RSZ	Rotor-swept Zone
SARA	Species at Risk Act
SCADA	Supervisory Control and Data Acquisition
SE	Searcher Efficiency
SK	Saskatchewan
SPL	Sound Pressure Level
TCU	Texas Christian University
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UV	Ultraviolet
WNS	White-nose Syndrome
WPC	Wildlife Preservation Canada
YT	Yukon Territories

Bat Species Acronyms Used in Text

Species	Acronym
Big brown bat (*Eptesicus fuscus*)	EPFU
Brazilian free-tailed bat (*Tadarida brasiliensis*)	TABR
California leaf-nosed bat (*Macrotus californicus*)	MACA
Cave myotis (*Myotis velifer*)	MYVE
Eastern red bat (*Lasiurus borealis*)	LABO
Evening bat (*Nycticeius humeralis*)	NYHU
Hawaiian hoary bat (*Lasiurus cinereus semotus*)	LACS
Hoary bat (*Lasiurus cinereus*)	LACI
Indiana bat (*Myotis sodalis*)	MYSO
Little brown bat (*Myotis lucifugus*)	MYLU
Long-legged myotis (*Myotis volans*)	MYVO
Silver-haired bat (*Lasionycteris noctivagans*)	LANO
Townsend's big-eared bat (*Corynorhinus townsendii*)	COTO
Tri-colored bat (*Perimyotis subflavus*)	PESU
Western pipistrelle (*Parastrellus hesperus*)	PAHE

1 INTRODUCTION

The Canadian Wind Energy Association (CanWEA) has developed this Wind Energy and Bat Conservation Review ("Review") to provide the wind industry, policy makers, and other stakeholders with the best-available science pertaining to the interaction between wind energy facilities and bats. The purpose of the Review is to present a scientific and ecological approach to supporting renewable energy production, aimed at meeting Canada's commitment of providing citizens with clean energy alternatives while minimizing potential impacts to bats. The Review was created by DNV GL, a leader in renewable energy and independent advisory services in coordination with Natural Resources Solutions, Inc. (NRSI) a leading biological services provider in Canada. Support was provided by CanWEA and its National Bat Committee (NBC). It is anticipated that CanWEA and the wind industry will endeavor to update the Review with new and relevant information as warranted.

The Review is based on the following information sources: an extensive search of published and unpublished literature primarily from Canada, the U.S. and Europe; discussions with the developers of emerging bat deterrent technology; NRSI's bat fatality and acoustic monitoring database (includes more than 50 project-years of post-construction fatality data and over 25,000 hours of acoustic monitoring data in Canada); and extensive monitoring results from operational wind energy facilities across North America. It is not the aim of the Review to prescribe specific guidelines or to identify management thresholds that should be implemented. Rather, it is intended to objectively summarize the scientific and practical background for feasible management objectives with respect to wind energy and bats. The Review provides an information source for the wind industry, as well as a mechanism for information-sharing among CanWEA members, agencies, and other stakeholders regarding potential management strategies at all phases of wind project development. It provides a ready reference to anyone seeking information about interactions between wind energy and bats.

1.1 Wind Energy and Bat Conservation

Over the last decade, wind energy has become the largest source of new electricity generation in Canada, with over 12,000 megawatts (MW) of currently installed capacity. The annual growth rate reached 23% over the last five years (1,438 MW/year). Canada's abundant wind resource means that there are opportunities to do more to maximize the economic and environmental benefits associated with wind energy development. In 2016 CanWEA, along with its partners, GE Energy Consulting, Natural Resources Canada and members of a Technical Advisory Committee released a Pan-Canadian Wind Integration Study [1]. The study showed that Canada can reliably and cost-effectively get more than one third of its electricity from wind energy. By examining four cross-Canada development scenarios, the study found no operational barriers to achieving 20% or 35% wind penetration (i.e., the fraction of energy produced by wind compared with total generation) by 2025. Clean wind energy can meet the growing electricity demand in Canada while reducing the impact of greenhouse gas (GHG) emissions from the electricity sector. According to the Intergovernmental Panel on Climate Change (IPCC), the earth's climate has warmed between 0.7 degrees Celsius (°C) and 1.1 °C over the past century, and most of the observed increase in globally averaged temperatures since the mid-20th century is likely due to the observed increase in anthropogenic GHG concentrations [2]. Table 1-1 presents a summary of current (as of 31 December 2017) installed wind energy capacity by province.

Table 1-1 Installed Wind Energy Capacity within Canada (as of 31 December 2017)

Province	Summary
Ontario Most wind energy installations in Canada	• 4,900 MW current installed capacity • 94 wind energy facilities • Approximately 7.5% of electricity demand
Quebec Second most wind energy installations in Canada	• 3,510 MW current installed capacity • 45 wind energy facilities • Approximately 5% of electricity demand
Alberta Third most wind energy installations in Canada	• 1,479 MW current installed capacity • 37 wind energy facilities • Approximately 8% of electricity demand
British Columbia	• 698 MW current installed capacity • 8 wind energy facilities • Approximately 2% of electricity demand
Atlantic Provinces	• 1,162 MW current installed capacity • 97 wind energy facilities • >50% in Nova Scotia, with approximately 9% of electricity demand
Manitoba	• 258 MW current installed capacity • 4 wind energy facilities • Approximately 4% of electricity demand
Saskatchewan	• 221 MW current installed capacity • 7 wind energy facilities • Approximately 3% of electricity demand
Northwest Territories and Yukon	• 10 MW current installed capacity • 3 wind energy facilities

The rapid pace of wind development across Canada as well as in the U.S. and Europe has led to questions about the potential impacts of wind energy on bats [3]–[7]. Bat fatalities are caused by a variety of human-caused and natural factors including intentional killing, environmental contaminants, collisions with energy infrastructure and buildings, forestry practices, and diseases [8], [9]. Wind energy facilities are recognized as posing a lower risk to bat population sustainability than other sources such as white-nose syndrome (WNS; a fungal infection which was estimated to kill over six million bats in North America over the last decade; see Appendix D), habitat loss, and the ongoing impacts of climate change [9]–[11], the latter of which represent the some of the greatest threats to bat populations worldwide [12]–[14]. At the same time, the wind industry recognizes that fatalities from collisions with operational wind turbines have been documented for several bat species, and continues to seek ways to avoid or minimize fatalities to bats. The interactions between wind energy development and bat populations are unknown, with modelling efforts suggesting potential effects for some species [13] and no effects for others [14]. The industry remains a committed partner in efforts to reduce these uncertainties.

Clean energy production is a crucial component for reducing global carbon emissions and combating the impacts of climate change, several of which are expected to have profound negative effects on bat populations. For instance, climate change will likely affect some bat species' ability to use habitats for critical life functions[1], may cause resource decoupling (i.e., timing of prey availability is no longer

[1] Reproductive success of female insectivorous bats is related directly to roost temperatures and water availability [371]. Fluctuations in precipitation, stream flow, and soil moisture could influence insect populations in such a way

compatible with bat ecological requirements; [15], [16]) and is expected to result in range contractions for temperate-climate species in particular [12]. The wind industry has a positive impact on climate change by reducing GHG emissions, and CanWEA believes that the wind energy industry can be a strong partner in the development of needed renewable energy while working to avoid and minimize impacts to bats. To this end, the wind industry has taken measures to avoid and minimize bat fatalities during project planning and operations. Industry leaders have also communicated with federal and provincial agencies to identify practical and effective measures for avoiding, minimizing, and mitigating potential impacts to bats.

As the wind industry expands, technology improves, and the ecological understanding of bat species increases, there exists an opportunity for the wind industry to continue to update and improve mitigation and minimization techniques for the conservation of bats while maintaining energy generation from renewable and sustainable sources. CanWEA and its members seek to produce clean, renewable energy while being good stewards of the environment, and this Review is intended to facilitate meeting those goals with respect to bats.

1.2 Objective and Scope of Review

In 2015 CanWEA formed the NBC, consisting of wind energy facility operators, project developers, and environmental consultants, to develop this Review and facilitate industry efforts to conserve bats. Over the last decade, regulatory agencies in several Canadian jurisdictions have taken steps to establish guidelines and protocols to minimize potential impacts to bats. Although it is appealing to have standardized approaches to avoidance and minimization available, these guidelines are often based on the findings of a limited number of early bat studies and do not necessarily facilitate an adaptive management approach that incorporates new research and technology into developing effective avoidance strategies. This Review provides the most current research pertaining to bats and wind energy and suggests a structured process for incorporating this knowledge into effective avoidance strategies. Furthermore, an adaptive management framework will be most effective when focused on the broader goal of maintaining stable bat populations, which can include avoidance measures as well as a more comprehensive suite of approaches. The goal of the Review is to provide the industry and other stakeholders with the tools and information needed to improve existing and proposed bat regulations, increase the effectiveness of management decisions for individual facilities, and provide a context in which the overall objective of these decisions is to ensure the sustainability of Canada's bat populations.

The Review will benefit wind energy developers and operators, as well as federal and provincial regulatory agencies and other stakeholders by:

- Enhancing the understanding of the existing information in order to drive science-based policy decisions;
- Providing avoidance, minimization, and compensation options which are being developed and evaluated by subject matter experts;

as to potentially decrease reliable prey availability for insectivorous bats [15], resulting in negative impacts to these species.

- Providing a consistent reference document that can be used across Canada to facilitate sound policy discussions and flexible mitigation plans;
- Providing an Adaptive Management Framework for guiding decisions to support updates and revisions of provincial and/or federal guidelines pertaining to bats and wind energy.

By consulting the Review, it is anticipated that the wind industry, regulatory agencies, and other stakeholders will be better positioned to make individual project decisions based on the best-available science. This will result in more efficient, appropriately targeted bat conservation, will provide the industry with financial and regulatory certainty, and will allow Canada to continue to expand renewable energy development using sustainable, science-based approaches to project siting and operations.

2 SITING AND DEVELOPMENT CONSIDERATIONS

The avoidance and minimization of impacts to bats begins at the siting stage of development. Information on bat communities, population numbers, habitat preferences, foraging and breeding behaviours, key habitat features, seasonal trends, and micro-siting considerations can aid in selecting pre-construction strategies for projects. Similarly, these components can inform efforts to develop science-based siting policies. The information regarding habitat associations and species phenologies provided in this chapter is based on general scientific knowledge about species life-histories. Whereas increased knowledge of bat ecology can be beneficial to developers, it is important to acknowledge that the existing scientific literature does not conclusively indicate avoidance of these habitats or phenologies will avoid the risk of bat collision fatalities. Research findings to date also do not indicate that increased bat activity, as measured by current, pre-construction acoustic monitoring methods, is associated with higher fatality rates at operating wind facilities [17], [18] (see Section 4.2.3.2). Although there is a lack of evidence regarding these potential risk factors, the wind industry has continued to employ avoidance and minimization strategies during siting, such as implementing setbacks and buffers around features associated with bat use. These knowledge gaps offer opportunities for the wind industry to work with entities engaged in bat research to reduce uncertainty pertaining to bat behaviour and potential collision risk.

2.1 Species, Habitats and Landscape Features

Prior to construction, it is beneficial to understand key life-history information for bats that occur in the region to help determine: 1) which species may potentially occur within the wind project area, 2) whether species of concern are likely to be present, 3) whether the wind energy facility is to be sited within or in proximity to habitats that may concentrate bats, and 4) when individual bat species are most likely to be active at the site based on foraging and breeding behaviours.

There are 20 bat species that occur in Canada [19]–[21], including the recently recorded Brazilian free-tailed bat (*Tadarida brasiliensis*) [22] but not including two species believed to be extirpated from Canada (big free-tailed bat [*Nyctinomops macrotis*] and evening bat [*Nycticeius humeralis*]). Detailed species profiles for each of these bats are provided in Appendix A. The information presented in each profile includes conservation status (provincial, federal, and/or international), key identification features, ranges (Canadian and international), current understanding of population numbers and/or trends, habitat preferences, foraging and breeding behaviours, and detailed legal listings. Details pertaining to conservation status ranks are provided in Appendix B. It should be noted that the approximate range maps provided are based on those developed by Bat Conservation International (BCI) and may not reflect the most recent occurrence data for all species [21]. In addition, because little is understood about population status and trends for most species, generalized assessments are provided based on the best available information. Key information from the species profiles is summarized in Table 2-1. Table 2-2 provides a reference table for developers to determine, based on the location of a planned or operating project, species that may be present and those that have federal or provincial protection status. Table 2-2 also indicates which bat species are most likely be affected by wind energy projects, based on species ecology and fatality data collected at other facilities. Potential effects to bats from operational wind energy facilities are discussed in more detail in Section 4.1.

Some general habitat types and landscape features are suspected to attract and potentially concentrate bats, but the likelihood of or extent to which the presence of these features increases collision risk at wind facilities is currently unknown. Whereas it is not generally possible to avoid all of these features when siting a wind energy facility, an assessment of the presence of specific forest and wetland types (see Table 2-1), abandoned mines / caves, aquatic resources (e.g., open water/waterbodies), ridgelines, rock habitat/talus slopes, shorelines/peninsulas, buildings, and roads at a site can help inform siting decisions. More detailed information pertaining to the potential use of these features by bats is provided in Appendix C.

Table 2-1 Summary of Key Species-Specific Information for the Bat Species in Canada

Bat Species	Ranges[1]	Population Trend and/or Status	General Habitat Preferences	Foraging and Breeding Behaviours
Migratory Bats				
Eastern Red Bat (*Lasiurus borealis*)	Saskatchewan, Manitoba, Ontario, New Brunswick, Nova Scotia, Prince Edward Island, Quebec, U.S., Mexico, Alberta, British Columbia [9], [23], [24][2]	Trend unknown, may be declining in some U.S. regions [25]; likely one of most abundant tree-roosting bats in the U.S. [19], [20], [26].	Mixed hardwood forests; forages in clearings, from ground level to tree canopy; roosts in sites that provide cover from the sides and above, but have an open flight path below [19].	Emerges from roost one half-hour after sunset to forage; feeds on insects from 5-20 mm in size; typically roosts alone [19], [20].
Hoary Bat (*Lasiurus cinereus*)	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador; U.S., Mexico, South America	Trend unknown [7]; common throughout range [20], [27]. Population size unknown but believed to be at or below 2.5 M [7].	Roosts in trees along forest edges or clearings, at 3 to 5 m above ground; forages above trees, along streams, and along lake shores [21], [28].	May travel as far as 39 km on first foraging flight of the night; typically feeds on insects, particularly moths; roosts alone [29].
Silver-haired Bat (*Lasionycteris noctivagans*)	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, U.S., Mexico	Trend unknown; common to rare within Canada [19], [30].	Prefers temperate hardwood forests nearby ponds or streams; forages predominantly in disturbed areas, including small clearings and roadways; roosts in tree cavities or under loose bark [19], [30].	Primarily forages during flight; feeds on a variety of small to medium sized insects; mates in the fall [19], [30], [31].
Western Red Bat (*Lasiurus blossevillii*)	U.S., Mexico, Central America, South America; may be found within British Columbia and Alberta [32], [33]	Trend unknown; low numbers (or absent) in Canada [19], [34].	Riparian habitats, especially with cottonwood (*Populus sp.*), walnut (*Juglans sp.*), oak (*Quercus sp.*), willow (*Salix sp.*), and sycamore (*Platanus sp.*); roosts underneath dense canopy of leaves; forages along forest edges, in small clearings, or around street lights [21], [33], [34].	Begins foraging 1 to 2 hours after sunset, and has two periods of foraging each night; limited information regarding breeding behaviour [32], [35].

Table 2-1 Summary of Key Species-Specific Information for the Bat Species in Canada

Bat Species	Ranges[1]	Population Trend and/or Status	General Habitat Preferences	Foraging and Breeding Behaviours
Resident Bats				
Big Brown Bat (*Eptesicus fuscus*)	Alberta, British Columbia, Manitoba, New Brunswick, Ontario, Quebec, Saskatchewan, U.S., South America	Trend unknown; common throughout most of range [19], [36].	Found in a variety of habitats including forests, meadows, agricultural lands and urban areas; roosts in tree cavities, under loose bark, in rock crevices, and in buildings or other structures [19], [21]. More active in winter and can tolerate a wider range of temperatures (including temperatures at 0 ° C) than many other bat species [36].	Begins foraging after sunset, foraging throughout the night; forms maternity colonies with 5 to 700 individuals [19], [36].
Brazilian Free-tailed Bat (*Tadarida brasiliensis*)	British Columbia [22], Mexico, U.S., South America	Trend unknown; likely uncommon in British Columbia but is possible the range is expanding [22]; considered common throughout most of its range outside of Canada [21].	Found in a variety of habitats including desert, pinion-juniper woodland, pine-oak forests [21]; this species was only recently recorded in British Columbia and little is known about its foraging and roosting habitat preferences within the province [22].	Emerges from roosts for nightly foraging at dusk [37]; forms maternity colonies in the millions in Texas [21]; species is known to fly and forage at higher altitudes and associated wind speeds [21], [38], [39] than other species.
California Myotis (*Myotis californicus*)	British Columbia, U.S., Mexico	Trend unknown; considered common throughout Canadian range in British Columbia [19].	Variety of habitats, including arid grasslands, coastal rainforests, and montane forests; forages over open areas, along forest edges, and over water; roosts under tree bark, in tree and rock crevices, under bridges, and in buildings [19], [21], [40].	Emerges for nightly foraging around sunset; may forage on warmer winter days; young are born in late June and early July [19].

Table 2-1 Summary of Key Species-Specific Information for the Bat Species in Canada

Bat Species	Ranges[1]	Population Trend and/or Status	General Habitat Preferences	Foraging and Breeding Behaviours
Eastern Small-footed Myotis (*Myotis leibii*)	Ontario, Quebec, U.S. [41]	Population is experiencing large declines due to WNS [19]; thought to be rarest bat species in eastern North America.	Deciduous or coniferous forests with hilly or mountainous terrain; forages over land and water at heights of 1 to 6 m; limited data is available on roosting preferences [19], [29], [42].	Travels to multiple foraging sites within a night, which may be up to 2 km from roosting location; a single pup is born in late May to early July [19], [29], [43].
Fringed Bat (*Myotis thysanodes*)	British Columbia, U.S., Mexico [44]	Trend unknown; population size unknown [45].	Grassland, shrub-steppe, and open ponderosa pine (*Pinus ponderosa*) forests in the U.S.; little is known about foraging and roosting habitat in Canada [46].	Diet composed largely of beetles, moths, flies, and lacewings; roosts in colonies of up to several hundred individuals; young are born from mid-June to mid-July [44]–[46].
Keen's Long-eared Bat (*Myotis keenii*)	British Columbia, U.S. [44]	Trend unknown; uncommon throughout range [19], [47], [48].	Prefers old-growth rainforests; forages within rainforests in proximity to water; roosts in hollow trees, snags, rock crevices, cliff faces, caves, bridges, and buildings [19], [21].	Adapted to forage in dense vegetation of coastal rainforests; leaves roost 20 to 30 minutes after sunset and returns approximately 2 hours before sunrise; young (one pup per reproductive female) are born in June or July [19], [49].
Little Brown Myotis (*Myotis lucifugus*)	Yukon, Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, U.S. [41]	Rapidly declining population due to WNS; uncommon throughout eastern range [21].	Forages over water, farmland, meadows, cliff faces; roosts in rock crevices, hollow trees, houses, and barns [21], [29].	Forages 1 to 6 m above ground or at water level; feeds on a variety of small insects; mates during late summer and early autumn; a single pup is born the following June [19], [21].

Table 2-1 Summary of Key Species-Specific Information for the Bat Species in Canada

Bat Species	Ranges[1]	Population Trend and/or Status	General Habitat Preferences	Foraging and Breeding Behaviours
Long-eared Myotis (*Myotis evotis*)	British Columbia, Alberta, Saskatchewan, Northwest Territories (possible), U.S., Mexico	Trend unknown; population size unknown but considered stable [50].	Prefers coniferous forests, typically at elevations of 2,000 to 2,500 m; roosts in tree cavities and bark crevices; forages near water and within tree canopies [19], [21].	Forages from 30 minutes after sunset to a few hours before dawn; a single young is born in June or July [19].
Long-legged Myotis (*Myotis volans*)	Yukon, Northwest Territories (possible), British Columbia, Alberta, Saskatchewan, U.S., Mexico	Population stable; population size unknown but found in colonies of 2,000 to 5,000 individuals throughout most of range [51].	Wooded habitats; forages over water and clearings, along cliff faces, and within and above forest canopies; roosts in mature trees, rock crevices, cliffs, and buildings [19], [21], [52].	Emerges from day roost at dusk; cold-tolerant species, often hunts in cooler temperatures; young are born in late June and July [19].
Northern Myotis (*Myotis septentrionalis*)	Yukon, Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, U.S. [44]	Canadian population rapidly declining due to WNS; likely consisted of over one million mature individuals before WNS [53].	Roosts under bark and in crevices, houses, and barns, often within 1 km of optimal foraging areas [19], [29].	Forages using both aerial hawking and gleaning, typically over a 65-ha area; mates during late summer and autumn at swarming sites [19], [29].
Pallid Bat (*Antrozous pallidus*)	British Columbia, U.S., Mexico, Cuba [19], [44]	Trend unknown; Canadian population estimated to consist of 250 to 1000 individuals [19], [54].	Arid and semi-arid regions; typically roosts in rock crevices; forages in open, sparsely vegetated regions [19], [55], [56].	Typically forages nearby day roost, emerging from roost relatively late in day; young are born in late June [19], [57].

Table 2-1 Summary of Key Species-Specific Information for the Bat Species in Canada

Bat Species	Ranges[1]	Population Trend and/or Status	General Habitat Preferences	Foraging and Breeding Behaviours
Spotted Bat (*Euderma maculatum*)	British Columbia, U.S., Mexico [44]	Trend unknown; Less than 1,000 individuals in British Columbia [19].	Grassland and coniferous forests within dry river valleys; roosts in rock crevices and cracks in cliffs; forages over marshes and in fields [19], [58], [59].	Typically forages within 10 km of roost site; establishes a foraging path that is followed for several days; limited information is known regarding breeding behaviour [19].
Townsend's Big-eared Bat (*Corynorhinus townsendii*)	British Columbia, U.S., Mexico [41]	Trend unknown; assumed rare as the extent of distribution is poorly known [19].	Prefers roosting in caves and abandoned mines; forages over wetlands, forest edges, and open woodlands [19], [60].	Forages within 2 km of day roost, emerging from day roost once fully dark; young are born from mid-June to mid-July [19].
Tri-colored Bat (*Perimyotis subflavus*)	Ontario, Quebec, New Brunswick, Nova Scotia, U.S., Mexico [44]	Canadian population rapidly declining due to WNS; population size unknown [53].	Roosts in tree foliage and clumps of lichen, caves and crevices, and rarely in barns and other buildings; typically forages over still water and rivers, but will also forage along forest edges and gaps in the forest [21], [53], [61].	Feeds on flying beetles, flies, moths, and leafhoppers; mates in autumn while swarming cave entrances; 1-2 pups are born in July [19], [53], [61].
Western Small-footed Myotis (*Myotis ciliolabrum*)	British Columbia, Alberta, Saskatchewan, U.S.	Trend unknown; population size unknown [62], [63].	Arid and semi-arid environments; roosts in rock crevices, caves, tunnels, under boulders and loose bark, and in buildings; forages along cliffs and rocky slopes, over open water, and around cottonwood trees [19], [63]–[65].	Emerges from roost shortly after sunset to forage; prefers to feed on small moths; small nursery colonies are formed in the spring; a single offspring is born between mid-June and late July [19], [63], [64].

Table 2-1 Summary of Key Species-Specific Information for the Bat Species in Canada

Bat Species	Ranges[1]	Population Trend and/or Status	General Habitat Preferences	Foraging and Breeding Behaviours
Yuma Myotis (*Myotis yumanensis*)	British Columbia, U.S., Mexico	Population stable; locally abundant but not regionally common in Canada [19].	Variety of habitats, including juniper (*Juniperus sp.*) and riparian woodlands, deserts with open water; roosts in caves, mines, buildings, and under bridges; primarily forages over water [19], [21], [66].	Forages for soft-bodied flying insects; easily disturbed when young are present [19], [21].

[1] Species range data were obtained from BCI [21], unless otherwise stated. For species range maps see the Bat Species Profiles in Appendix A.
[2] Recent occurrences in Alberta and British Columbia are not represented in BCI public data and thus not displayed on range maps. However, eastern red bats have been found as fatalities at wind energy facilities in Alberta [9], [23]. This and other evidence [24] suggests that the species range includes Alberta, British Columbia, and likely western portions of Saskatchewan.

Table 2-2 Species Summary and Potential for Impacts from Wind Turbines

Species	Province / Territory where Present[a]												Status Listings		Representation in Observed Fatalities[d]
	AB	BC	MB	NB	NL	NT	NS	ON	PE	QC	SK	YT	SARA Listing[b]	Provincial Listing[c]	
Migratory Bats															
Eastern red bat	X[e]	X[e]	X	X			X	X	X	X	X				Common
Hoary bat	X	X	X	X	X[f]		X	X	X	X	X				Common
Silver-haired bat	X	X	X	X			X	X	X	X	X				Common
Western red bat	X	X													No Records in Canada[g]
Resident Bats															
Big brown bat	X	X	X	X				X		X	X				Uncommon
Eastern small-footed myotis								X		X				ON	Very Uncommon
Brazilian free-tailed bat		X													No Records in Canada[h]
California myotis		X													No Records
Fringed bat		X											X		No Records
Keen's long-eared bat		X											X		No Records
Little brown myotis	X	X	X	X	X	X	X	X	X	X	X	X	X	MB, NB, NS, ON, PE, YT	Uncommon
Long-eared myotis	X	X									X				Very Uncommon
Long-legged myotis	X	X				X[i]					X	X[i]			Very Uncommon
Northern myotis	X	X	X	X	X	X	X	X	X	X	X	X	X	MB, NB, NS, ON, PE, YT	Very Uncommon
Pallid bat		X											X		No Records
Spotted bat		X											X		No Records
Townsend's big-eared bat		X													No Records in Canada[j]

Table 2-2 Species Summary and Potential for Impacts from Wind Turbines

Species	Province / Territory where Present[a]												Status Listings		Representation in Observed Fatalities[d]
	AB	BC	MB	NB	NL	NT	NS	ON	PE	QC	SK	YT	SARA Listing[b]	Provincial Listing[c]	
Tri-colored bat				X			X	X		X			X	NB, NS, ON	Very Uncommon
Western small-footed myotis	X	X									X				No Records
Yuma myotis		X													No Records

[a] No bat species have been recorded as occurring in Nunavut, therefore it is not presented in this table. For detailed species range data and maps see the Bat Species Profiles in Appendix A.

[b] Listed as a Species of Special Concern, Threatened, or Endangered under Schedule 1 or 3 of the SARA.

[c] Provincial listing for each province/territory is presented only if a species is threatened or endangered (legally protected in the province). For more detailed rankings and ranking descriptions see Appendices A and B.

[d] Representation in post-construction fatality studies at wind facilities. Common = Species which are commonly found as fatalities at wind energy facilities. Uncommon = Species which are less commonly found as fatalities at wind energy facilities. Very Uncommon = Species which are not typically or uncommonly observed as fatalities at wind energy facilities. No Records = Species for which no fatalities have been observed at wind energy facilities.

[e] Although the map for eastern red bat does not show the species occurring in Alberta, bats have been found as fatalities at wind energy facilities in the province [9], [23]. This and other evidence [24] suggests that the species range includes Alberta, British Columbia, and likely portions of western Saskatchewan.

[f] Species occurs infrequently and unpredictably in province, which is outside of their normal range.

[g] Species found rarely as fatalities at wind energy facilities within its range in the U.S.

[h] Species is found commonly as fatalities at wind energy facilities within its range in the U.S., but there are no records of fatalities in Canada.

[i] Potential to be found in province, but not part of normal range.

[j] Virginia big-eared bat (*Corynorhinus townsendii virginianus*), a subspecies of Townsend's big-eared bat, has been rarely observed as fatalities at wind facilities in the U.S.; no other subspecies fatalities have been observed in the U.S. or Canada.

2.2 Avoidance Strategies

Avoiding impacts to bats begins during the project siting and design phase. Wind turbines are micro-sited based on a variety of constraints including wind resources, wildlife concerns, cultural sites, landscape, and noise or shadow flicker concerns. When practicable, effective micro-siting to balance these concerns may avoid and minimize impacts to individual bats while avoiding costly monitoring and mitigation measures at later project stages. It is important to note, however, that scientific studies have not been conducted to evaluate the effectiveness of adhering to specific "setback" distances between potential concentrating habitats and wind turbines for reducing bat fatalities during operation. Setback recommendations for turbine placement are therefore not provided in this Review.

2.2.1 Micro-siting

Micro-siting considerations for proposed wind energy facilities can include an analysis of habitat or landscape features that have the potential to concentrate bats. While avoidance of these features has not been scientifically shown to reduce fatalities during operations, analysis of habitat and landscape conditions at a site can be informative based on current knowledge of species ecology and habitat associations (see Table 2-1). Because they are based on ecological understanding of species and habitats, avoidance measures in general have the potential to reduce some types of impacts (e.g., habitat loss). Therefore, where practicable, developers may consider avoiding or minimizing habitat alteration in areas that are confirmed to contain important or significant habitat or concentration areas for target bat species.

Assessment of individual turbine placement and potential effects on bats will vary by project and will be dependent on the region, habitats, and species associated with a project location. Ecological factors such as species-habitat associations, species movement patterns and behaviour continue to receive intensive study and are expected to better inform siting decisions over time. Knowledge gaps pertaining to these factors remain; for instance, gaining a better understanding of northern myotis foraging and migration patterns relative to roost areas is considered a high priority in several regions [67], whereas more is known about the characteristics of habitats that can attract large mixed concentrations of bats.

2.2.2 Landscape Modifications

Some landscape modifications made during the installation of wind energy facilities, such as creation of water features or removal of trees may create favourable conditions for aerial insects on which bats feed. Landscape modifications that may be beneficial to local bat populations may simultaneously result in a greater risk of collision to individual migratory bats that forage, commute, or migrate through newly created linear landscape features [68]. Wind energy developers may consider the potential effects of landscape modification during the siting phase and make adjustments to avoid or reduce potential negative impacts on bat species that could be concentrated in these areas. Individual bat species have varied habitat requirements and will thus be affected differently by landscape alterations.

2.3 Summary

Avoidance and minimization measures employed during siting may be effective for reducing risk to bats, and are typically less costly than the minimization and compensation strategies most commonly used during operations. Where practicable, siting avoidance measures can thus be considered in balance with other siting concerns (e.g., noise constraints, cultural/historical features), as attention to potential issues at this stage can prevent costly remedies later in the process. In order to effectively minimize impacts, project developers can seek access to information regarding the bat species present at the site as well as sufficient ecological information to evaluate habitat features. In general, key questions for developers to address at the early stages of development include:

- What species occur in the Province?
- Which species' ranges overlap the project location?
- Of species that may occur in the project, which are considered high conservation priority?
- What habitat features are associated with high priority species or high bat concentrations in the region?

By comparing this information regarding bat species to an inventory of habitat features at a site, key features may be identified and siting modified to potentially minimize impacts as practicable. However, it is important to note that in many cases, data are lacking concerning the effectiveness of avoidance at the siting stage. Currently available recommendations and best practices for avoidance at this stage of development are based primarily on ecological information for bats, and additional research is needed to better establish effectiveness.

3 POST-CONSTRUCTION MONITORING AND ESTIMATING IMPACTS TO BATS

Operational wind energy facilities across Canada are typically required to conduct post-construction monitoring for bat fatalities resulting from interactions with wind turbines. Monitoring is conducted in order to estimate bat fatality rates and total bat fatalities at individual operational wind energy facilities. Fatality studies can be useful for the following objectives, contingent upon study design:

- estimating fatality rates for groups of interest;
- characterizing species composition of fatalities;
- identifying factors related to fatalities (e.g., weather conditions, proximity to habitat features);
- comparing estimated fatality rates to regulatory or adaptive management thresholds;
- comparing estimated fatality rates among wind energy facilities or between geographic regions;
- comparing actual fatality rate estimates with predicted impacts based on pre-construction studies (e.g., low, moderate, high);
- understanding the need for and effectiveness of mitigation and adaptive management, as well as providing data to optimize mitigation design to balance efficacy with financial impact [69].

Post-construction fatality monitoring for wind energy facilities presents significant challenges due to the competing needs for precision and affordability. Fatality monitoring typically consists of searches for bat fatalities beneath turbines at set intervals. Because bat carcasses may go undetected for a variety of reasons, incomplete information is collected regarding the actual number of fatalities or fatality rate at the facility. To minimize uncertainty regarding the actual number of fatalities, a statistical estimator is used to calculate an estimate of this value based on the number of fatalities detected during monitoring surveys. There are multiple variables that can significantly affect final fatality estimates and should be considered when developing a post-construction monitoring plan. Factors that can affect final estimates include monitoring protocols implemented, choice of estimator, abilities of personnel conducting searches, and site conditions (e.g., numbers and types of scavengers in the area, land cover).

3.1 Fatality Monitoring Design

Estimation of fatality rates at wind energy facilities is based on the number of carcasses found during carcass searches conducted under operating turbines. Statistical estimators of fatality rates are based on assumptions regarding design, and it is important that monitoring protocols be designed to match the underlying statistical assumptions of the estimator chosen for a facility. Although designs vary, some basic components apply to all monitoring designs: trained observers (searchers) search plots around a subset of operating turbines following a systematic protocol. Additionally, bat fatality surveys often are conducted concurrently with those for birds, and this may affect survey design.

Plot Design. Considerations for plot design include the size and shape of plots, spatial pattern of search, and spacing of searched areas within the plot. Searches are typically conducted on square plots centered on the turbines; this plot shape facilitates the use of linear transects for searching, although circular plot designs also are sometimes used. Size of the plot is variable, depending on the taxa of interest and the height of turbines, because the proximity of carcasses resulting from collision to a turbine varies as a function of the size of the animal and the height at which it is struck; smaller, lighter carcasses accumulate closer to turbines than large carcasses. Due to the small size of bats, the fall zone around turbines is relatively small for this taxonomic group, with approximately 90 percent of bat carcasses expected to fall within 35-40 percent of maximum blade tip height (MBTH) from the turbine [69], [70]. Empirical findings have thus far indicated that >95 percent of bat carcasses are found within 60 meters of modern turbines [71]–[73], although the size of the fall zone increases with increasing turbine height [74]. If plot design constraints prevent full sampling of the spatial carcass distribution around turbines, correction methods are available for use during data analysis (see Section 3.2.3). When square plots are used, searches are typically conducted along transects spaced 5-10 m apart. Choice of transect spacing is determined by anticipated difficulty of detection, which is in turn driven by land cover and carcass size. Transect spacing is typically closer for bats than for other taxa.

Frequency of Searches. Search frequency is typically matched to the rate at which carcasses are removed by scavengers, thereby becoming unavailable for detection by observers. Statistical estimators of fatality rates provide more precise estimates as the frequency of searches increases (i.e., search interval decreases). In a typical monitoring design for bats, search frequency will be designed to match anticipated mean carcass persistence time and distribution of persistence times; for example, if bat carcasses are expected to persist a mean of five days, search frequency might be set at once per five days. Once carcass persistence is measured in bias trials (described below), the search frequency is often adjusted to optimize precision of the estimates subject to economic constraints. The greatest precision in fatality estimates will result from a search interval short enough that a large proportion of carcasses persist through the interval [70].

Subset of Turbines Searched. It is often prohibitively expensive to search all turbines in a wind energy facility, and fatality searches therefore typically concentrate on sampling a representative subset of turbines. Sampling of approximately 30 percent of turbines is generally considered adequate to estimate fatality rates at large wind farms; however, larger samples may increase the precision of the estimates. Additionally, where land cover or topography limits the size of search plots, it may be desirable to increase the number of turbines searched to maintain the desired precision. Ensuring that the subset of turbines selected for fatality searches is representative of the whole wind farm can be accomplished via stratification based on position in the facility and land cover type. There are also some monitoring designs that use a subset of turbines to delineate the carcass distribution around turbines in combination with limited sampling at all turbines (e.g., the “road and pad” method; [72]). The goal of these designs is to use the carcass distribution measured at the subset of turbines to develop an adjustment factor for the raw counts on small plots at all turbines.

Search Seasons. Many wind energy facilities experience winter conditions that either make it unsafe to sample or dramatically impact parameters such as searcher efficiency and carcass persistence. In such cases, fatality monitoring may be limited to three seasons, and the resulting fatality estimates need to be understood as three-season, rather than annual estimates. In practice, there is little loss of information in three-season designs, because bats are generally inactive during winter months.

3.2 Sources of Bias

Bias refers to a systematic difference between a fatality estimate and the true fatality rate (unknown) it is designed to estimate. A primary goal of fatality monitoring is to produce fatality rate estimates having minimum bias. To adjust for the primary sources of potential bias that can affect fatality estimates, the following should be considered when estimating total bat fatalities at a wind energy facility [69], [75]–[78]:

- Carcass persistence/scavenger removal;
- Searcher efficiency; and
- Proportion of carcass distribution searched.

Although these potential sources can be quantified via bias trials and used to adjust fatality rate estimates, each statistical estimator has vulnerabilities and sensitivities to extreme values that must be taken into account

3.2.1 Carcass Persistence

Carcass persistence (CP) accounts for carcasses that are removed from the search area and are therefore not available to be found by the searcher. Carcasses may be removed from the search area by factors such as scavenging animals (e.g., coyotes, raccoons, raptors), decomposition, weather, or human influences (e.g., tilling, maintenance of tile drainage). Carcass persistence is beyond the control of the study and must be adjusted for in the fatality estimates. In order to adjust for carcass persistence, it is necessary to estimate the probability of persistence through a search interval. Carcass persistence is typically estimated by the placement of carcasses within the search area, or similar nearby habitat, and monitoring them for a pre-determined length of time (i.e., a set number of search intervals) or until each carcass disappears. Carcasses for persistence testing can be collected from among those found at a facility or may be surrogate species. Carcasses that are similar or identical to species likely to occur at a wind energy facility provide the most accurate estimates of carcass persistence; for example, mice are commonly used as surrogates for bat carcasses, but recent studies have shown that the use of mice underestimates bat carcass persistence, which can lead to inflated estimates of bat fatality rates as well was higher than necessary search frequencies (e.g., [79]).

3.2.2 Searcher Efficiency

Searcher efficiency refers to the effectiveness of the searcher in finding carcasses available to be found within the search area. Searcher efficiency (SE) may vary by searcher, season, terrain, vegetation type and height, weather, location of a facility, or size of carcass. For example, SE typically is higher for larger carcasses, flatter terrain, shorter vegetation, and clearer weather conditions. In a recent meta-analysis, Smallwood reported that SE for bats in North America ranged from approximately 0.10 to 0.60, depending on visibility class of the land cover [74]; the Pennsylvania Game Commission reported a similar range (0.15-0.70) for bats at 12 facilities in Pennsylvania [73]. In order to accurately account for the factors influencing SE, it is therefore necessary to incorporate the variation found at the facility. Searcher efficiency can be estimated by the placement of carcasses within the search area and the observation of how many of the placed carcasses are actually found by the searcher. Important considerations in the testing of searcher efficiency include ensuring that all searchers are tested, making all tests blind (i.e., the searcher is not aware that they are being tested), and testing sufficiently in each set of conditions (e.g., season, land cover class) in which the searchers are expected to search for carcasses. The SE tests can be stratified so that they proportionally represent the major land cover types or visibility classes that are being searched, and/or conditions documented so that they can be explicitly treated in the fatality modelling process. In addition, separate SE and scavenger removal trials may provide for simpler and more distinct results. Simultaneous trials (i.e. combined bias trials) may confound estimated SE rates if scavengers remove carcasses prior to the next search (i.e., between search intervals) [75].

3.2.3 Proportion of Carcass Distribution Searched

Proportion of the carcass distribution that is searched is important because the distribution of carcasses around a turbine is skewed, with greater numbers of carcasses near the turbines and accumulation of carcasses decreasing as a function of distance from the turbine [71]–[73], [77], [78]. It can therefore be important to correct fatality estimates for the proportion of the distribution searched due to limitations in the size of the search area, to avoid introducing bias caused by incomplete searches [77]. Additionally, not all areas within a search plot are searchable, and any unsearchable areas reduce the proportion of the carcass distribution effectively searched. Unsearchable areas can be estimated by mapping the types and extent of vegetation or other ground conditions present within the search area and used to adjust the proportion of the carcass distribution searched. Huso and Dalthorp note that using a data driven model of carcass density by distance from turbines improves the accuracy and precision of fatality estimates more than increasing the size of the search area when the complete carcass distribution is not sampled by the fatality searches [77], and this can also prove to be more economical than expanding search areas. Finally, searching a subset of turbines at a wind energy facility leaves a portion of the cumulative carcass distribution at the wind energy facility unsampled, and this is generally adjusted for by the statistical estimator.

3.2.4 Other Factors

There are other factors that may influence the actual number of fatalities, but are typically not considered in fatality estimates due to difficulties of measurement or assumptions that they are not important/frequent contributors to actual overall fatality at a site. Some of these factors that may bias the estimated fatalities include [75], [80]:

- injured bats which may move (or fly) outside the search area before dying and are therefore not detected/counted, but may later succumb to their injuries;
- fatalities in the search area that may have been caused by unrelated sources (e.g., naturally-occurring fatalities, interactions with agricultural equipment, vehicular collisions); and
- fatalities may not occur at equal rates at all turbines, and bias can be introduced due to selection of a non-representative subset of turbines for sampling. For example, sampling only at turbines near suitable bat habitat may produce overestimates of fatality rate. To obtain a representative sample, it is therefore necessary to stratify the sample by land cover and position within the facility to ensure representative sampling.

3.2.5 Reporting

Fatality monitoring results are most useful if they are comparable to those from other sites so that broader regional or continental questions can be addressed; reporting is therefore most useful if it provides complete information regarding methods, raw data, analyses and metrics so that comparison to other projects is possible. Although fatality rates are often reported on a per-turbine basis (i.e. fatalities/turbine/year), variation in the output capacity of turbines limits the comparative value of this metric. Reporting fatalities on a per-MW or per-MWh basis is useful for comparisons among wind energy facilities of varying ages and turbine types. For example, Smallwood reported that in 71 fatality monitoring reports he reviewed, the per-turbine output capacity ranged from 0.04 to 3.0 MW [74]. Because fewer of the newer high-capacity turbines are needed to provide a given output, a per-turbine fatality rate makes direct comparisons among projects using different-sized turbines difficult and inaccurate.

Examples demonstrating the effect of calculating fatality rates on a per-turbine vs. per-MW basis under various simulated conditions (number of turbines, turbine capacity) are provided in Table 3-1. In each scenario, bat fatality rates on a per-turbine (scenario 1) or per-MW basis (scenario 2) are held constant across projects for comparison. Reliance on per-turbine fatality estimates as the capacity of turbines changes can cause misleading conclusions regarding the impacts of a wind energy facility when compared to other facilities with varying turbine sizes and models. For example, if adaptive management triggers are constructed in terms of per-turbine fatality rates, the result can be triggering of the same management response for vastly different net impacts at wind energy facilities with different turbine types. As shown by Table 3-1, facilities of the same nameplate capacity and having the same per-turbine fatality rate can have dramatically different total impact on bats (scenario 1). If fatalities are instead reported on a per-MW basis, facilities having the same nameplate capacity and fatality rate will also have the same total impact on bats (scenario 2), which facilitates comparison among wind farms as well as assessment of cumulative impacts. Another consideration of importance to fatality rate reporting is that point estimates of rates are statistical estimates of central tendency; these may be less useful in a management context than the confidence intervals around the point estimates, which are typically also reported.

Table 3-1 Comparison of Per-turbine and Per-megawatt (MW) Fatality Rates at Four Hypothetical Wind Projects

Parameter	Project 1	Project 2	Project 3	Project 4
Simulated Project Conditions				
# turbines	50	100	10	33
MW per turbine	2	1	3.3	1
Total MW	100	100	33	33
Scenario 1 – Bat fatality rate (reported as per turbine per year)				
Bat fatality rate (# / turbine / year)	5	5	5	5

Annual site-total fatality estimate	250	500	50	165
Result	Projects 1 and 2 assumed to have equal collision impact on bats, based on a per/turbine reporting basis, although total impact is significantly lower at Project 1.		Projects 3 and 4 assumed to have equal collision impact on bats, based on a per/turbine reporting basis, although total impact is significantly lower at Project 3.	
Scenario 2 – Bat fatality rate (reported as per MW per year)				
Bat fatality rate (#/MW/year)	5	5	5	5
Annual site-toal fatality estimate	500	500	165	165
Result	Projects 1 and 2 assumed to have equal collision impact on bats based on a per/MW reporting basis, which accurately reflects total impact.		Projects 3 and 4 assumed to have equal collision impact on bats based on a per/MW reporting basis, which accurately reflects total impact.	

Other components of fatality monitoring reporting include summaries of raw carcass-search data, summaries of bias trial findings, descriptions of empirical carcass distributions. Methods used for searches, including plot sizes, search frequencies, seasons, sample of turbines, variations from planned protocols, and measurement of covariates such as cover type or weather variables are typically reported; as are methods employed for bias trials. Fatality monitoring reports containing these elements facilitate impact assessment, adaptive management, and meta-analysis across facilities.

3.3 Estimators

There are numerous statistical approaches available to extrapolate an annual fatality rate from a sample of fatalities at a wind energy project [70], [76], [81]–[86]. Each of the statistical estimators accounts for sources of bias and adjusts the estimate to create a relatively unbiased estimate of the true fatality rate at a given project.

Several commonly used or recently proposed estimators are summarized below in Table 3-2 and Table 3-3 for comparative purposes, although they do not represent an exhaustive list of possible estimators. The following fatality estimators are described in Appendix E:

- Jain Estimator [87];
- Ministry of Natural Resources and Forestry (MNRF) Adapted Estimator [88];
- Shoenfeld-Erickson Estimator [84];
- Huso Estimator [70];
- Wolpert Estimator [76]; and
- FatalityCMR [83].

Additionally, an international committee comprised of biologists, statisticians, wind energy experts and others is developing software for a generalized estimator, with the goal of creating a program that automatically selects the most appropriate estimator for a given dataset and provides the flexibility of multiple estimators in a single package [88], [89] (see Section 3.4 for further discussion).

Each estimator is an expression of the expected (i.e., mean) fatality count as a function of the actual fatality count and a combination of these other measured variables. Fatality estimators are based on the following general principles [76], [92]:

(1) Estimated Fatality = $\dfrac{\text{\# of carcasses observed}}{\text{\# of carcasses available to be found} \cdot \text{probability of being found}}$

(2) $$C = \frac{c}{\pi}$$

Where:

C = estimated number of fatalities
c = number of carcasses actually found
∏ = probability of carcass availability and detection

The selection of an appropriate fatality estimator is strongly linked to the monitoring methods that are implemented at a particular site as well as the conditions at that site (e.g., scavenging rates). Certain fatality estimators are more accurate for more frequent search events, combined searcher efficiency and scavenger removal trials, the size of the search area examined around each turbine, the specific results of searcher efficiency or scavenger removal trials, or the land use within the search area. In most cases, the estimators have been designed around assumptions regarding the search protocols, and changes to the protocols may necessitate changes to the estimators used for analysis. For example, the MNRF adapted estimator is derived from an estimator that assumes a 14-day search interval [93], but is used with a shorter search interval in Ontario; this may not be appropriate without modification of the estimator.

Fatality estimators, including those summarized here, do not typically perform well (i.e., they have low precision and may be biased) when used with rare events (i.e., fewer than 5 to 10 detected carcasses). If the detection of rare events is the goal of fatality surveys, a different type of estimator may be needed.

Table 3-2 Summary of Estimator Considerations and Assumptions from Appendix E

Estimator	Region in Canada (Known Use or Recommended by Province)[a]	Search Interval	Bleed-through[b]	Scavenger Removal Trial	Searcher Efficiency Trial	Proportion Distribution Searched
Jain Estimator	None	2 days	No	Exponential distribution Half proportion of carcasses remaining between intervals	Multiple opportunities to find fatality	All areas of the search area are equally likely to contain a fatality
MNRF Adapted Estimator	Ontario – required for all projects constructed after 2012	3 or 4 days	No	Linear Proportion of carcasses remaining between intervals	Point-in-time	All areas of the search area are equally likely to contain a fatality
Shoenfeld-Erickson Estimator	No formal provincial guidance; however, frequently used in Alberta pre-2013	~7 days	Yes	Exponential distribution Average time to removal	Point-in-time	Not considered, but can be adjusted for proportion
Huso Estimator	Recommended by Alberta, British Columbia, Quebec	Variable (effective search interval)	No	Modified for observed distribution (Exponential, Log Logistic, Log Normal, or Weibull) Average time to removal	Multiple opportunities to find fatality	Not considered, but can be adjusted for proportion
Wolpert Estimator	Recommended by British Columbia	Shortest mean persistence of carcasses	Estimated value determined from trials (0 to 1)	Exponential, Log Logistic, Log Normal, or Weibull	Multiple opportunities to find fatality	Not considered, but can be adjusted for proportion
FatalityCMR Estimator	None	Consistent Search Protocols				

[a] See Provincial Guidelines in Appendix I for more detail.

[b] Bleed-through is defined as the circumstance in which a carcass that is not detected by a searcher persists until a subsequent search, making it available for future detection.

Table 3-3 Summary of Estimator Benefits, Limitations, Biases from Appendix E

Estimator	Benefits	Limitations	Biases
Jain Estimator	• Calculates an empirical estimate of the carcass removal rate.	• No bleed-through (i.e., undiscovered fatalities from one search to another); however, carcasses may be missed on the first search day, but later found on a subsequent search day. • Carcass persistence is calculated differently for this estimator (i.e., the proportion of carcasses remaining after half the length of the search interval), and additional monitoring effort may be required if this estimator is intended to be used in combination with other estimators. • Necessary to retrieve carcasses at the end of each searcher efficiency trial day (i.e., carcasses retrieved at the end of the day rather than being placed and monitored until they are found) which increases staff effort and cost. • Assumes search detection rate does not change over time or among searchers.	• Overestimates fatality rate.
MNRF Adapted Estimator	• Searcher efficiency and scavenger removal trials are completed separately, which may provide for simpler and more distinct results.	• California Energy Commission (CEC) guidelines recommend adjustment of the equation if search interval is changed from 14 days; however, it does not appear that the MNRF adapted estimator has been adjusted to account for the change to a 3 to 4-day search interval. • Searcher efficiency and scavenger removal trials are completed separately, which will require more staff effort and time to implement than other protocols that combine the two trials. • Scavenging activity is assumed to be linear, but this is not likely the case as fresh carcasses will likely be more appealing to scavengers than older carcasses. • No bleed-through is assumed; however, carcasses may be missed on the first search day, but later found on a subsequent search day. • Carcasses are assumed to fall equally throughout the search area, but does not account for the density of carcasses decreasing with distance from turbine and that unsearched areas often tend to be further away from the turbine. • Shorter search interval requires more staff effort and time to implement. • Search areas may be voluntarily cleared to increase the proportion area searched, which can increase the cost and effort for the wind energy facility. • Increased staff effort and cost to retrieve carcasses at the end of each searcher efficiency trial day (i.e., carcasses retrieved at the end of the day rather than being placed and monitored until they are found). • If visibility for carcass searches needs to be improved within the search area through clearing, as recommended in the Ontario guidelines, this will result in added costs.[a]	• Overestimates fatality rate, when searcher efficiency is low and carcass persistence is high.

Table 3-3 Summary of Estimator Benefits, Limitations, Biases from Appendix E

Estimator	Benefits	Limitations	Biases
Shoenfeld-Erickson Estimator	• Assumes exponential carcass removal, with fresh carcasses being more appealing to scavengers and becoming less appealing over time. • Incorporates bleed-through (i.e., undiscovered carcasses from one search to another), with searchers having the ability to find carcasses on subsequent search days. • Applying a bleed-through approach to searcher efficiency trials can reduce staff effort, as carcasses placed for trial do not require retrieval after each trial day. This is more reflective of the ability of searchers, allowing them to find carcasses on subsequent search days.	• A single searcher efficiency value is restrictive, as searcher efficiency is likely to vary over time, season, habitat types, search conditions, and between searchers, and is better suited for shorter search intervals. • Assumes searcher efficiency rate does not change over time (i.e., all carcasses, old and new, have the same probability of discovery), which may not be the case as carcasses that have been overlooked once are more likely to be overlooked on subsequent visits, especially if they decompose. • Search area size is not accounted for (i.e., treats search areas of varying sizes equally)	• Underestimates fatality rate, when carcass persistence and searcher efficiency variables deviate from constant over time.
Huso Estimator	• Allows for incorporation of covariates into the estimates of searcher efficiency, which facilitates calculation of different searcher efficiencies for different seasons, search conditions, habitat types, and searchers. • Works well when carcass persistence times are long (average 32 days) and usually when search intervals of >14 days are used. • Useful for long search intervals, as it accounts for carcasses that may be missed when the likelihood of them persisting between search intervals is very low (<1%), in the effective search interval. • Software facilitates distance-weighted modeling of carcass distribution.	• No bleed-through (i.e., undiscovered fatalities from one search to another); however, carcasses may be missed on the first search day, but later found on a subsequent search day. • When persistence times are shorter (average 4.2 days) and search intervals are shorter (usually 1 to 7 days), this estimator tends to overestimate the number of fatalities. • Necessary to retrieve carcasses at the end of each searcher efficiency trial day (i.e., carcasses retrieved at the end of the day rather than being placed and monitored until they are found) which increases staff effort and cost. • Alberta guidelines recommend 1 to 7-day search intervals, which can lead to fatality overestimates under some conditions.[a]	• Overestimates fatality rate, when carcass persistence is low and search intervals are short or if carcass persistence time is longer than the search interval. • Underestimates fatality rate, when carcass persistence is high.
Wolpert Estimator	• Searcher efficiency accounts for a proportion of carcasses that may have been missed by a searcher and are still in a discoverable condition. • Carcass persistence rate assumptions can be modified based on observed distributions. • All of the bias adjustment values necessary for this estimator are obtained in the one 60-day trial period and can be established for the monitoring program.	• The 60-day trial may need to be repeated to account for seasonal variability and may lead to delays. • Large carcasses may persist beyond the end of a 60-day trial, and it may be necessary to extend the trial to get accurate bleed-through estimates in these cases which increases staff effort and cost.	• None reported.
FatalityCMR Estimator	• Potential to provide more accurate results due to the software's ability to account for time and age variations in all parameters and due to the assumption of bleed-through.	• The software does not allow for varying protocols at different turbines, or in searcher efficiency or scavenger removal trials. There is no flexibility in the program for missed search days due to inclement weather, temporary inaccessibility, or other safety concerns.	• None reported.

[a] See Provincial Guidelines in Appendix I for more detail.

3.3.1 Case Study

The following case study was constructed using data generated to represent various hypothetical scenarios that may be encountered at operational wind energy facilities. This exercise is provided as an exploratory tool to demonstrate the impact of estimator choice on fatality rate estimates, based on representative values and probable scenarios from NRSI's database of post-construction fatality data collected across Canada. The case study does not contain real data collected at operational projects or estimation results for those projects. The goal of this exercise is to explore the ways in which various conditions impact the behaviour of each estimator and ultimately, the fatality estimates. Specific conditional parameters were designed to vary among scenarios, including the length of the search interval, searcher efficiency rate, and carcass persistence rate. For the purpose of the case study, carcass distribution (i.e., proportion of area in which carcasses occur) has been considered equal in all scenarios, and all scenarios are assumed to have observed five bat fatalities per turbine during one year of monitoring.

The primary purpose of the case study is to help operators select an appropriate estimator for each project that will minimize potential bias based on site-specific conditions. It can be difficult to assess true accuracy, or likelihood of bias, of a specific equation without completing controlled studies or detailed simulations. However, for the purpose of this case study, the most accurate estimators are considered to be those that result in similar estimated values (e.g., similar to other estimators) in a given scenario. Clear outliers, high or low, are assumed to present biased results and would thus not be recommended for use under conditions similar to those presented. Table 3-4 presents the results of the estimators in the various scenarios of the case study.

Table 3-4 Case Study Presenting Estimated Bats/Turbine/Year Using Different Estimators. Outlier Results are Indicated in Bold Text.

Scenarios	Jain Estimator[1]	MNRF Adapted Estimator[1,2]	Shoenfeld-Erickson Estimator	Huso Estimator	Wolpert Estimator[3]
Short Search Interval (3.5 days/twice-weekly)					
Low SE, low CP rate	21.32	**84.03**	23.86	27.81	26.82
Low SE, high CP rate	14.29	18.80	**8.53**	16.51	14.51
High SE, low CP rate	9.95	**39.22**	12.27	12.98	12.80
High SE, high CP rate	6.67	8.77	6.27	7.70	7.35
Moderate Search Interval (7 days/weekly)					
Low SE, low CP rate	47.62	**Null (CP=0)**	44.24	45.65	45.30
Low SE, high CP rate	16.81	**25.06**	12.14	18.94	17.24
High SE, low CP rate	22.22	**Null (CP=0)**	21.05	21.31	21.24
High SE, high CP rate	7.84	11.70	7.62	8.84	8.53
Long Search Interval (14 days/bi-weekly)					
Low SE, low CP rate	**Null (CP=0)**	**Null (CP=0)**	87.03	87.83	87.12
Low SE, high CP rate	23.04	**49.26**	19.56	24.40	23.19

Table 3-4 Case Study Presenting Estimated Bats/Turbine/Year Using Different Estimators. Outlier Results are Indicated in Bold Text.

Scenarios	Jain Estimator[1]	MNRF Adapted Estimator[1,2]	Shoenfeld-Erickson Estimator	Huso Estimator	Wolpert Estimator[3]
High SE, low CP rate	**Null (CP=0)**	**Null (CP=0)**	40.65	40.99	40.67
High SE, high CP rate	10.75	**22.99**	10.52	11.39	11.17

The searcher efficiency (SE) rate is categorized as low (0.35) or high (0.75).

A low carcass persistence (CP) rate denotes low carcass persistence (high scavenging activity), and a high CP rate denotes high carcass persistence (low scavenging activity). The CP values for each estimator are derived from:

- low CP rate: logarithmic persistence model: y=-5.363ln(x)+9.714. Average persistence time = 2.3 days.
- high CP rate: exponential persistence model: y=11.662e-0.091x. Average persistence time = 11.8 days.

Parameters were derived as “low” and “high” (or short persistence and long persistence) based on NRSI's experience with post-construction monitoring in Canada. Example data was chosen based on how these data are collected and then modeled in most Canadian applications. Modeled data were then used to identify the values applicable for each scenario. In some cases, low CP resulted in all carcasses being considered scavenged between search events. In such cases model estimate of CP = 0, and a fatality estimate could not be calculated (i.e., Null).

[1] Due to the way this estimator calculates CP, an estimate cannot be calculated (i.e. Null value) in cases where all carcasses are removed between search events.

[2] The MNRF adapted estimator has not been corrected for search interval length in these scenarios; however, this is a correction that can be made for this estimator. CP has been calculated based on persistence on the first four search dates after placement (i.e. 14 days following a twice-weekly schedule).

[3] Theta (θ) is the proportion of undiscovered carcasses that remain discoverable and has been assumed at a low to moderate level of 0.25 for all scenarios.

When the search interval is longer than carcass persistence (e.g., low CP rate scenarios), Shoenfeld-Erickson, Huso, and Wolpert estimators are very similar, which was also observed by Warren-Hicks et al. [76]. In cases where the search interval is shorter than carcass persistence (i.e., high CP rate scenarios, where average persistence is longer than 3.5 and 7 days, but shorter than 14 days), estimates of fatality from Huso and Wolpert remain similar, with Shoenfeld-Erickson estimates deviating slightly lower, particularly when searcher efficiency is low.

The MNRF adapted and Shoenfeld-Erickson estimators are substantially influenced by searcher efficiency and carcass persistence rates, and low values (i.e., poor searcher efficiency and rapid scavenging activity) have a strong influence on the final fatality estimate. The MNRF adapted estimator consistently appears to bias high (i.e., relative to other estimator results), likely due to no bleed-through (i.e., undiscovered fatalities persisting from one search to another) in this estimator. The bias appears to be greater if either one (or both) of SE and CP are low; in high SE and high CP scenarios, the MNRF adapted estimator produced similar (but still higher) fatality estimates to all other estimators. The Huso and Wolpert estimators remained fairly consistent in the different scenarios, although higher with low searcher efficiency and carcass persistence.

3.4 Summary

The fatality monitoring design and selection of an appropriate fatality estimator are strongly linked for any wind energy facility. Important aspects to be considered in monitoring bat fatalities at a facility include the following:

1. Selection of an appropriate plot size and configuration for carcass searches.
2. Selection of a consistent search frequency within each study period (e.g., season) that provides for enough opportunities to find fatalities based on carcass persistence rates.
3. Selection of an appropriate subset of turbines for sampling to balance estimation accuracy and economy of efforts.
4. Inclusion of bias trials to provide adjustment factors for sources of bias such as carcass persistence, searcher efficiency.
5. Methods that account for bleed-through will improve fatality estimates. This can be accomplished through the use of multiple-search searcher efficiency trials, where testing occurs over multiple search events for each cohort of carcasses placed in order to account for the ability for searchers to find fatalities they may have missed previously.
6. Independent of the selection of an estimator, distance-based, predictive modeling (e.g., [77], [78]) can be employed to determine what proportion of the carcass fall zone is encompassed by searchable portions of a search area. The fall zone of fatalities varies by turbine height and carcass size and using predictive modeling also provides a means of optimizing search area size.
7. Until a universal, generalized estimator is fully developed (see below), fatality estimates derived from a variety of estimators may be appropriate, accompanied by discussions of potential sources of bias and rationale for how each estimator is expected to perform under the study's search protocol. This will allow for a more comprehensive analysis of bat fatality at wind energy facilities, and will better inform adaptive management strategies so that they are more accurate, targeted, and effective.

Fatality estimators account for sources of bias by adjusting raw survey data, but existing estimators differ in their underlying assumptions and can generate significantly different estimates even when using same data. Thus, the misuse of an estimator or use of estimators that do not account for all sources of imperfect detection prevent direct comparisons of results among wind energy facilities. A universal estimator that ensures good quality estimates under varying circumstances is still lacking [80], [82]. However, a committee consisting of an international collaboration of biologists, statisticians, wind energy experts, and others (GenEst Committee) is currently developing a generalized fatality estimator for bats and other wildlife potentially affected by wind energy facilities [90], [91].

Once developed, the generalized estimator, or GenEst, will allow users to test various estimator assumptions such as carcass persistence patterns and carcass detectability over time, that are specific to individual projects. GenEst will guide the user in selecting the most appropriate assumptions for a given set of circumstances, rather than focusing on which estimator is the most applicable for a given situation. The goal of GenEst will be to provide an unbiased fatality estimator that allows for comparability among projects. If attained, industry-wide adoption of GenEst is expected to provide user-friendly guidance on study design, increase efficiency and thus reduce costs of fatality monitoring programs, and improve the accuracy of fatality estimates to more efficiently target avoidance and minimization strategies, where appropriate. The final GenEst product is expected to be available in 2018 [90]. Until such an estimator is available, however, the most appropriate estimator for each wind energy facility will depend on site-specific conditions and the design of the study, bearing in mind the assumptions, benefits, limitations, and biases of each estimator. If an appropriate estimator is selected at each site, it will be more likely to present unbiased fatality estimates, resulting in a collective dataset that is representative of wind energy facilities across Canada. This will result in bat fatality estimates that more accurately depict the true rate of wind turbine caused bat fatalities, and will allow for direct comparisons among wind energy facilities to identify geographic regions of higher risk.

4 OPERATIONAL AVOIDANCE AND MINIMIZATION

Avoidance and minimization refers to steps taken to prevent impacts of an activity or to minimize those impacts where it is not practicable to completely avoid them. Operational avoidance and minimization strategies are designed to reduce bat fatalities at operational wind energy facilities, and implementation of these strategies often takes into account a facility's characteristics (e.g., turbine properties and layout, wind speeds, proximity to bat concentration areas such as bat hibernacula). The overall goal of these strategies is to reduce bat fatalities at operational wind energy facilities. The objective of this chapter is to provide an assessment of the operational strategies currently being employed or considered, including evaluation of their effectiveness for reducing risk to bats. Avoidance and minimization strategies for bats can be categorized broadly into three categories: 1) general avoidance measures, 2) curtailment, and 3) deterrents. This chapter provides a summary of the operational options currently available in these three categories to avoid and minimize impacts to bats.

General avoidance measures minimize features of a site that may attract bats to areas near turbines. They do not directly affect turbine operations or renewable energy production. Curtailment is the reduction or modification of renewable energy production to the grid during operations. For the purposes of this document, bat-targeted curtailment is defined as altering turbine operations in order to reduce the risk to bats [3], [4], [94]. Curtailment to reduce risk to bats has become the most commonly employed operational avoidance and minimization approach at wind energy facilities, but is generally only initiated when observed bat fatalities are appreciably higher than anticipated during project siting or exceed agency-defined thresholds (e.g., a defined amount of bat fatalities observed in a year, see Appendix I). The economic and environmental impacts of curtailment regimes can be significant, however, and can vary between projects, regions, and years (see Section 4.2.2.3).

The financial and environmental costs associated with lost renewable energy generation due to curtailment have led to an interest in developing alternative avoidance and minimization solutions to be used in place of, or in conjunction with, curtailment measures, including the use of deterrents. Deterrents refer to methods used to deter bats from entering the rotor-swept zone (RSZ; i.e. the altitude described as the upper and lower limits of the rotor-swept area and the spatial extent of a wind energy facility) of turbines during operations. Several potential methods for deterring bats are reviewed in Section 4.2.3.1 including acoustic, surface coating, lighting, and electromagnetic radiation approaches. These approaches to deterring bats are in early stages of development and effectiveness testing, and are not yet practicable for widespread use. This chapter provides an assessment of peer-reviewed evaluations only; information pertaining to preliminary laboratory and field test results, research schedules, and technical considerations for specific emerging deterrent technologies are provided in Appendix G.

To provide a consistent metric of effectiveness in the summaries in Table 4-2 and Appendix F, results of studies evaluating the effectiveness of avoidance and minimization methods (including the use of deterrents) were considered statistically significant based on an alpha level of 0.05 (i.e., 5% probability that the reported result was not related to the strategy under evaluation) unless otherwise noted.

4.1 Species Considerations

4.1.1 Potential for Wind Turbine Collisions

As has been noted previously in this document, bat fatalities are caused by a variety of human-caused and natural factors including intentional killing, environmental contaminants, collisions with energy infrastructure and buildings, forestry practices, and disease [8], [9]. Wind energy infrastructure overall has been shown to pose a much lower risk to bat population viability than WNS and other threats [95], and the likelihood of collision with wind turbines varies substantially among species. For example, recent modeling efforts have identified the potential for wind energy fatalities to influence population trajectories for hoary bat [7], whereas analyses for northern myotis have indicated that fatalities from wind facilities do not impact population stability [14]. Overall, much uncertainty remains about the potential costs (e.g., collisions) and benefits (e.g., mitigating climate-caused impacts) that wind energy poses to individual bat species, and research to reduce this uncertainty continues. Furthermore, the potential roles of ecological processes believed to influence collision risk at wind facilities, including the availability of nearby prey, potential attraction to turbine movement and sound, and the perception of turbines as potential roost sites [4], are currently unclear. The wind energy industry therefore continues to seek ways to avoid or minimize fatalities to bats from operational wind turbines, and remains a committed partner in efforts to improve understanding of risk to individuals and the efficacy of available measures.

In North America, approximately 80% of bat fatalities recorded at wind energy facilities represent migratory species, with the remaining proportion of fatalities representing year-round resident species [4]. Specifically, individual hoary bats, eastern red bats, and silver-haired bats typically comprise the majority of fatalities at wind energy facilities in Canada and the U.S. For example, a comprehensive assessment of fatalities from 64 wind facilities across nine provinces was completed in 2016 by Environment and Climate Change Canada [13]. The study examined fatality data published between 2002 and 2013, and found that most fatalities were comprised of the migratory hoary bat (34% of all carcasses observed), silver-haired bat (25%) and eastern red bat (15%), with the federally-listed little brown myotis representing 13% of observed fatalities, and big brown bat representing 9%. All other species represented 1% or less of observed fatalities. Similarly, post-construction fatality data from Ontario were recently analysed. Using anonymous data collected by NRSI from 2009 to 2015 at 23 wind energy facilities across Ontario, with a total of 2,513 bats collected and identified to species-level, the three common migratory species (i.e., hoary, silver-haired and eastern red bats) combined to represent 76% of all observed fatalities (NRSI unpublished data; Figure 4-1). It is important to note that there is a large dataset available for the province of Ontario compared to other Canadian provinces due to the larger number of recently developed wind facilities. In addition, this dataset includes data prior to and following the introduction and spread of WNS (see Appendix D) and therefore represents fatality distributions by species that may not be consistent with more current studies. A similar assessment was conducted in Quebec. Anonymous data collected from 2007 to 2015 at 24 wind facilities indicated that hoary, silver-haired and eastern red bats comprised 70% of 188 observed bat fatalities [96].

Table 4-1 provides a general assessment of the potential for wind energy facilities to impact individual bat species, based on various factors including migratory status (i.e., migrant vs. resident), documented fatalities at wind facilities, and potential population vulnerability (e.g., population size, species range). In general, migratory bats throughout Canada appear to be at greater collision risk from wind turbines than resident species. Three long-distance migratory species in particular, including hoary bat, eastern red bat, and silver-haired bat are more likely to be found as fatalities around turbines in Canada than are resident bat species. Other migratory bats appear to be less affected, potentially due to the rarity of these species and smaller populations overall. The western red bat, for example, is a migratory bat for which there are very few documented fatalities from wind turbines. This and several other species are also only present in a very limited portion of Canada, with no data to suggest a high risk of impact by wind energy facilities in Canada. It should also be noted that potential risk relates only to projects within each species range in Canada. Finally, it is important to acknowledge that fatalities at wind facilities may represent bats from one localized site or multiple regions [97], [98].

Individual resident bats have also been documented as fatalities at wind energy facilities, although potential impacts to these species are generally considered very low (typically representing less than 1% of the proportion of total fatalities). Big brown bats, which are the most common resident bat species throughout most of Canada, appear to have experienced greater numbers of collisions from wind turbines than other resident bats across Canada. Little brown myotis have also been documented as fatalities at wind energy facilities in larger numbers than other resident bat species, a finding likely driven by the fact that a large proportion of monitoring activities occurred pre-WNS incursion into Canada; populations of this species were thus relatively high at the time of monitoring (Appendix D). Therefore, recent studies show far fewer little brown myotis fatalities than studies conducted pre-WNS [99].

Table 4-1 Potential for Individual Bat Species Fatalities due to Wind Turbines in North America

Bat Species	Resident / Migrant	Potential for Fatalities from Wind Turbines
Big Brown Bat	Resident	• Big brown bat is a common species throughout most of its range, although it is uncommon to rare in the Yukon and Northwest Territories [19]. Population size and trends are unknown although it is suspected to be increasing due to an increase in anthropogenic structures in which they may roost [36]. • Wind energy facilities have reported fatalities of big brown bats. Based on reported Canadian fatalities of this species, 16.3% of 6,643 bat carcasses found across Canada were big brown bat [99]. • A low to moderate probability of big brown bat fatalities is expected at wind facilities.

Table 4-1 Potential for Individual Bat Species Fatalities due to Wind Turbines in North America

Bat Species	Resident / Migrant	Potential for Fatalities from Wind Turbines
Brazilian Free-tailed Bat	Resident	• Brazilian free-tailed bat is considered common throughout its range in western and southern U.S. [21]. The species has only recently been recorded on Salt Spring Island in British Columbia and it is possible that local reproductive colonies may exist elsewhere in British Columbia [22], and is considered uncommon or rare in British Columbia. It is unknown if the species occurs elsewhere in Canada. Population size and trends are unknown in British Columbia, but considered stable throughout most of its range outside of Canada [20]. • Wind energy facilities in California, Oklahoma, and Texas have reported high proportions of fatalities of Brazilian free-tailed bats (41-94%) [4], [39], [68], [100], [101] likely because the species is known to fly at higher altitudes and associated wind speeds [21], [38], [39] than other species. There are no recorded fatalities of the Brazilian free-tailed bat in Canada. • A moderate probability of Brazilian free-tailed bat fatalities is expected at wind facilities in the U.S.; however, there are no records of fatalities of the species in Canada.
California Myotis	Resident	• California myotis is considered a common species throughout its range in British Columbia [19]. Population size and trends are unknown [102]. • A very low probability of California myotis fatalities is expected at wind facilities due to limited documented fatalities of this species.
Eastern Red Bat	Migrant	• Eastern red bat is likely one of the most abundant tree-roosting bats in the U.S. [45], [103]. Population size and trends are unknown although there has been some evidence that numbers are declining in the U.S. [19], [104]. • Wind energy facilities have reported fatalities of eastern red bat. Based on reported Canadian mortalities of this species, 20.9% of 6,643 bat carcasses found across Canada were eastern red bat [99]. Out of 14,166 fatality records from 182 publicly available project reports in North America, 3,282 eastern red bats were documented (23.2% of the total fatalities) [105]. Estimates of cumulative fatalities of eastern red bat from 2000 to 2011 for all regions combined in the U.S. and Canada suggest the species comprises about 22% of total turbine caused fatalities [106]. • A moderate to high probability of eastern red bat fatalities is expected at wind facilities.
Eastern Small-footed Myotis	Resident	• Eastern small-footed myotis is thought to be the rarest bat species in eastern North America [19]. Eastern small-footed myotis population has experienced large declines due to WNS; for example, bat populations at several hibernation sites in Ontario have decreased by more than 90% [41]. • Eastern small-footed myotis appears to be at very low risk of wind turbine impacts, with only two fatalities known to have occurred in Canada [105]. Both were found during the fall (early September) in Ontario at the same facility [107]. Based on reported Canadian mortalities of this species, 0.04% of 6,643 bat carcasses found across Canada were eastern small-footed myotis [99]. Turbine fatalities are uncommon for this species because it tends to use rocky substrates for roosting habitat and vegetated landscapes for foraging [108]. • A very low probability of eastern small-footed myotis fatalities is expected at wind facilities.

Table 4-1 Potential for Individual Bat Species Fatalities due to Wind Turbines in North America

Bat Species	Resident / Migrant	Potential for Fatalities from Wind Turbines
Fringed Bat	Resident	• Population size and trends are unknown [45], [46]. • A very low probability of fringed bat fatalities is expected at wind facilities due to limited documented fatalities of this species.
Hoary Bat	Migrant	• Hoary bat is considered a common species throughout its range [20], [27]. Population size and trends are generally unknown but population size is believed to be at or below 2.5 million [7]. • Wind energy facilities have reported fatalities of hoary bat. Based on reported Canadian mortalities of this species, 29.2% of 6,643 bat carcasses found across Canada were hoary bat [99]. Hoary bats represent the largest proportion (approximately 40 to 50%) of documented bat fatalities at turbines in the U.S. and Canada [109]. Of a total of 14,166 fatality records from 182 publicly available project reports in North America, there were 5,132 hoary bats documented (36.2% of the total fatalities) [105]. Estimates of cumulative fatalities of hoary bat from 2000 to 2011 for all regions combined in the U.S. and Canada comprised about 38% of total turbine caused fatalities [106]. • The hoary bat is one of the most widespread bats in North America. This bat is a generalist and as a result uses a wide range of habitat features. Relatively low wind speeds, low moon illumination, low barometric pressure, and relatively high cloud cover are important predictors of hoary bat activity [109]. • Studies in Canada have indicated that male hoary bats experience more fatalities than females, possibly because the males may use the turbines for display during reproductive periods the way they normally use a tall tree [110]. Additionally, mortalities tend to be skewed more towards adults rather than juveniles as a result of mating behaviour [111]. However, since this species' migration behaviours are largely unknown, it is difficult to predict and assess the impacts of turbine mortalities [111]. • Although based on limited demographic data, recent modeling efforts suggest that wind energy fatalities may contribute to population declines in hoary bat [7]. • A moderate to high probability of hoary bat fatalities is expected at wind facilities.
Keen's Long-eared Bat	Resident	• Keen's long-eared bat is uncommon throughout its range, and the lack of available records makes it difficult to determine population size or trends [19]. Therefore, there have been no estimates of the population size or trend of this species [47], [48]. • A very low probability of Keen's long-eared bat fatalities is expected at wind facilities due to limited documented fatalities of this species.

Table 4-1 Potential for Individual Bat Species Fatalities due to Wind Turbines in North America

Bat Species	Resident / Migrant	Potential for Fatalities from Wind Turbines
Little Brown Myotis	Resident	• The little brown myotis is considered uncommon throughout its range in eastern North America [21]. Population size is unknown, although likely consisted of more than one million individuals before the arrival of WNS [53]. Eastern Canadian subpopulations of little brown myotis are rapidly declining due to WNS and there has been an estimated 94% overall decline in numbers [53]. In addition, WNS was recently confirmed in a little brown myotis individual discovered in Washington [11] and suggests the potential for this disease to spread west in Canada as well. • Wind energy facilities have reported fatalities of little brown myotis. Based on reported Canadian mortalities of this species, 11.6% of 6,643 bat carcasses found across Canada were little brown myotis [99]. In Canada, little brown myotis accounted for 13% of all bat mortalities from wind turbines (approximately 7,000 individuals), with most (88%) fatalities occurring in Ontario [112]. Estimates of cumulative fatalities of little brown myotis from 2000 to 2011 for all regions combined in the U.S. and Canada were approximately 6% of total fatalities [106]. Of 14,166 fatality records from 182 publicly available project reports in North America, little brown myotis was about 8.1% of the total fatalities [105]. It is important to note that this dataset includes data prior to and following the introduction and spread of WNS and may not be representative of current species distributions and seasonal patterns. • Little brown myotis may be at an increased collision risk because they may behave like a migratory bat [113], which can include traveling distances of up to 150 to 450 km from summer roosts [114]. • A low to moderate probability of little brown myotis fatalities is expected at wind facilities.
Long-eared Myotis	Resident	• Population size and trends of the long-eared myotis are unknown but population size is considered stable [50]. • Wind energy facilities have reported fatalities of long-eared myotis. Estimates of cumulative fatalities of long-eared myotis from 2000 to 2011 for all regions combined in the U.S. and Canada were <0.01% of total fatalities [106]. • A very low probability of long-eared myotis fatalities is expected at wind facilities.
Long-legged Myotis	Resident	• Population size and trends of long-legged myotis are unknown but considered stable throughout its range [51]. • Wind energy facilities have reported fatalities of long-legged myotis. Based on reported Canadian mortalities of this species, 0.03% of 6,643 bat carcasses found across Canada were long-legged myotis [99]. Estimates of cumulative fatalities of long-legged myotis from 2000 to 2011 for all regions combined in the U.S. and Canada were <0.01% of total fatalities [106]. Of 14,166 fatality records from 182 publicly available project reports in North America, long-legged myotis were <0.1% of the total fatalities [105]. • A very low probability of long-legged myotis fatalities is expected at wind facilities.

Table 4-1 Potential for Individual Bat Species Fatalities due to Wind Turbines in North America

Bat Species	Resident / Migrant	Potential for Fatalities from Wind Turbines
Northern Myotis	Resident	• Population size is unknown, although likely consisted of more than one million individuals before the arrival of WNS [53]. Eastern Canadian populations of northern myotis are rapidly declining due to WNS and there has been a 94% overall declines in numbers since 2010 [53]. • Wind energy facilities have reported fatalities of northern myotis. Based on reported Canadian fatalities of this species, 0.31% of 6,643 bat carcasses found across Canada were northern myotis [99]. Northern myotis also accounted for slightly less than 1% of all fatalities from wind turbines (approximately 440 individuals) in Canada [112]. Estimates of cumulative fatalities of northern myotis from 2000 to 2011 for all regions combined in the U.S. and Canada were <0.01% of total fatalities [106]. Of 14,166 fatality records from 182 publicly available project reports in North America, there were 43 northern myotis recorded (0.3% of the total fatalities) [105]. • A very low to low probability of northern myotis fatalities is expected at wind facilities. In the U.S., the U.S. Fish and Wildlife Service (USFWS) has determined that risk from wind turbines is sufficiently low to exempt lethal take by wind turbines from prohibition under the Threatened listing of the species [115].
Pallid Bat	Resident	• Pallid bat is rare in Canada [55]. Population size in Canada is unknown, but is estimated to consist of at least 250 and less than 1,000 mature individuals [19], [54]. • No fatalities of pallid bats have been reported at wind energy facilities in North America [4] and there are no data demonstrating the presence of this species at existing wind energy facilities [116]. • This species commonly forages near the ground; however, it may fly higher when dispersing and migrating [116]. Risk to pallid bats is greatest within a few miles of a day roost site, where most of the foraging activity can occur [34]. Risk for this species may increase during dispersal when the young leave the natal roost site and fly straight out from the roost (i.e., 80 feet or higher from the ground) [117]. • A very low probability of pallid bat fatalities is expected at wind facilities.
Silver-haired Bat	Migrant	• Silver-haired bat is considered common to rare within its range in Canada depending on the season and region [19]. Population size and trends are unknown [19], [30]. • Wind energy facilities have reported fatalities of silver-haired bats. Based on reported Canadian mortalities of this species, 21.2% of 6,643 bat carcasses found across Canada were silver-haired bat [99]. • A moderate to high probability of silver-haired bat fatalities is expected at wind facilities.
Spotted Bat	Resident	• Spotted bat is considered rare within its range in British Columbia [19]. Population size is estimated to be less than 1,000 individuals [19]. • There are currently no reports of spotted bat mortalities at wind energy facilities [81], [118], [119]. • A very low probability of spotted bat fatalities is expected at wind facilities.

Table 4-1 Potential for Individual Bat Species Fatalities due to Wind Turbines in North America

Bat Species	Resident / Migrant	Potential for Fatalities from Wind Turbines
Townsend's Big-eared Bat	Resident	• Townsend's big eared bat is considered rare within its range in Canada [19]. Population size and trends are unknown [19]. • Wind turbines pose a low risk to individual Townsend's big-eared bats [120]. The Virginia big-eared bat (*Corynorhinus townsendii virginianus*), a subspecies of Townsend's big-eared bat which is non-migratory and forages below the location of turbine blades, has a low collision risk [121]. This is likely applicable to Townsend's big-eared bat [122]. • A very low probability of Townsend's big-eared bat fatalities is expected at wind facilities.
Tri-colored Bat	Resident	• Tri-colored bat was formerly one of the most common species in eastern Canada [21]. Population size is unknown; however, there has been a 94% overall decline in numbers of the eastern Canadian subpopulations since 2010 due to WNS [53], [123]. • Wind energy facilities have reported fatalities of tri-colored bat. Based on reported Canadian fatalities of this species, 0.18% of 6,643 bat carcasses found across Canada were tri-colored bat [99]. At some wind energy facilities in the eastern U.S., tri-colored bats accounted for as many as 25.4% of fatalities [4], whereas in Canada, <0.1% of all carcasses found during carcass searches were tri-colored bats [112]. Of 14,166 fatality records from 182 publicly available project reports in North America, tri-colored bats were 4.4% of the total fatalities [105]. Estimates of cumulative fatalities of tri-colored bat from 2000 to 2011 for all regions combined in the U.S. and Canada were about 6% of total fatalities [106]. • This species' low turbine-related fatality numbers may be a result of its differences in behaviour or habitat preferences, or because of its smaller population size which makes them uncommon around wind energy facilities [112]. • A very low to low probability of tri-colored bat fatalities is expected at wind facilities.
Western Red Bat	Migrant	• Population size and trends are unknown and there are few records of western red bat outside of California [34]. The number of individuals in Canada is believed to be quite low or absent [32]. • Western red bat is considered migratory, but fatalities associated with wind energy facilities are rare for this species [97]. No mortalities of western red bat have been documented in Canada [99]. This may be due to the western red bat being rare in Canada. Estimates of cumulative fatalities of western red bat from 2000 to 2011 for all regions combined in the U.S. and Canada ranged from 69 to 143 (<0.01 % of total fatalities) [106]. Out of 14,166 fatality records from 182 publicly available project reports in North America, only 9 western red bats were documented [105]. • A very low probability of western red bat fatalities is expected at wind facilities.
Western Small-footed Myotis	Resident	• Population size and trends of western small-footed myotis in British Columbia, Alberta, and Saskatchewan are unknown [62], [63]. • A very low probability of western small-footed myotis fatalities is expected at wind facilities due to limited documented fatalities of this species.

Table 4-1 Potential for Individual Bat Species Fatalities due to Wind Turbines in North America

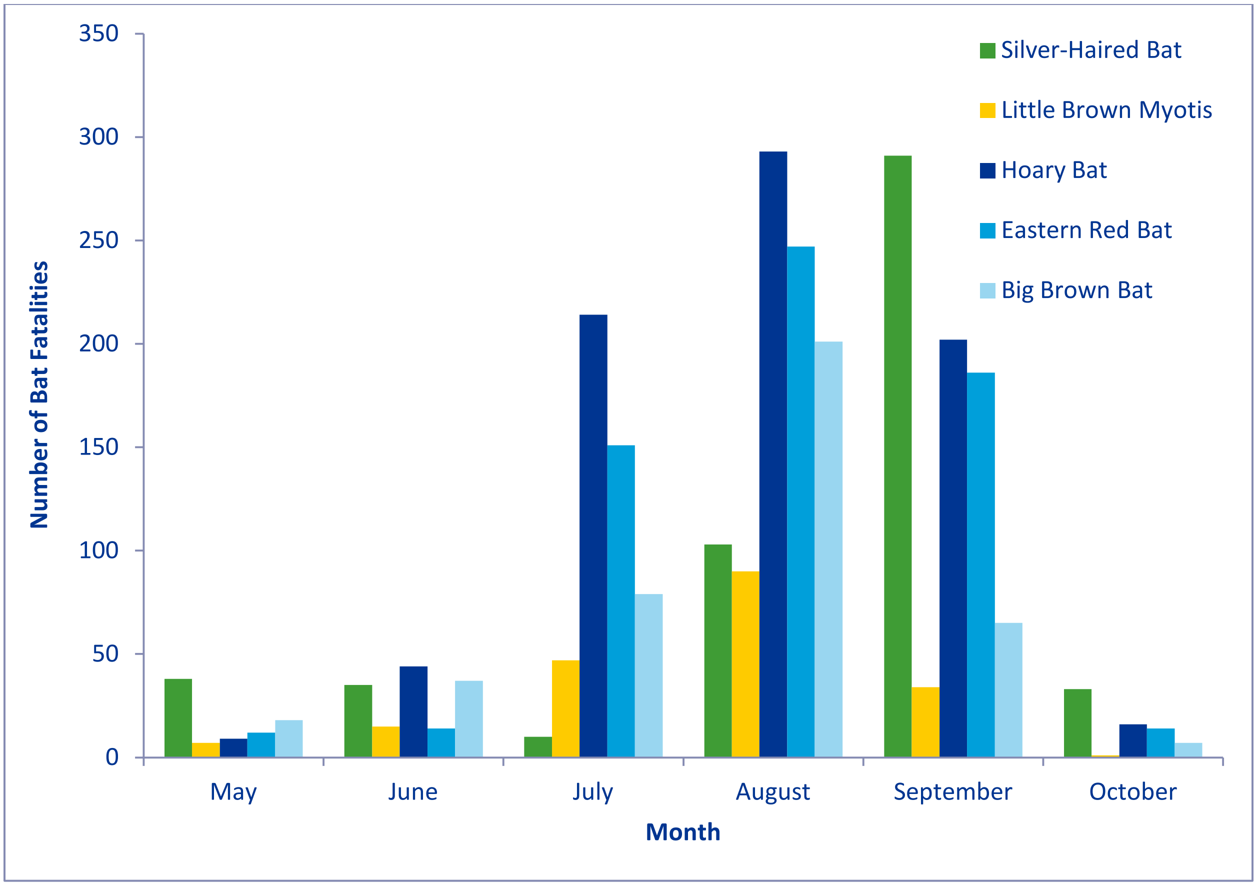
Bat Species	Resident / Migrant	Potential for Fatalities from Wind Turbines
Yuma Myotis	Resident	• The Yuma myotis is globally common and global population levels are stable; however, Yuma myotis may be threatened by riparian area habitat loss [21], [66]. Within Canada, the Yuma myotis may be considered locally abundant, but is typically not regionally common [19]. • A very low probability of Yuma myotis fatalities is expected at wind facilities due to limited documented fatalities of this species.

4.1.2 Seasonal Patterns

Information on seasonal trends in bat activity can inform avoidance and minimization strategies considered during operations. Although little is known about the migratory behaviour (e.g., flight paths, height, navigation, stopover habitat) of the species most commonly observed at wind facilities [97], [98], collision risk is expected to be greater during flights to and from breeding grounds, as migratory bats typically fly more frequently and at great distances during these time periods.

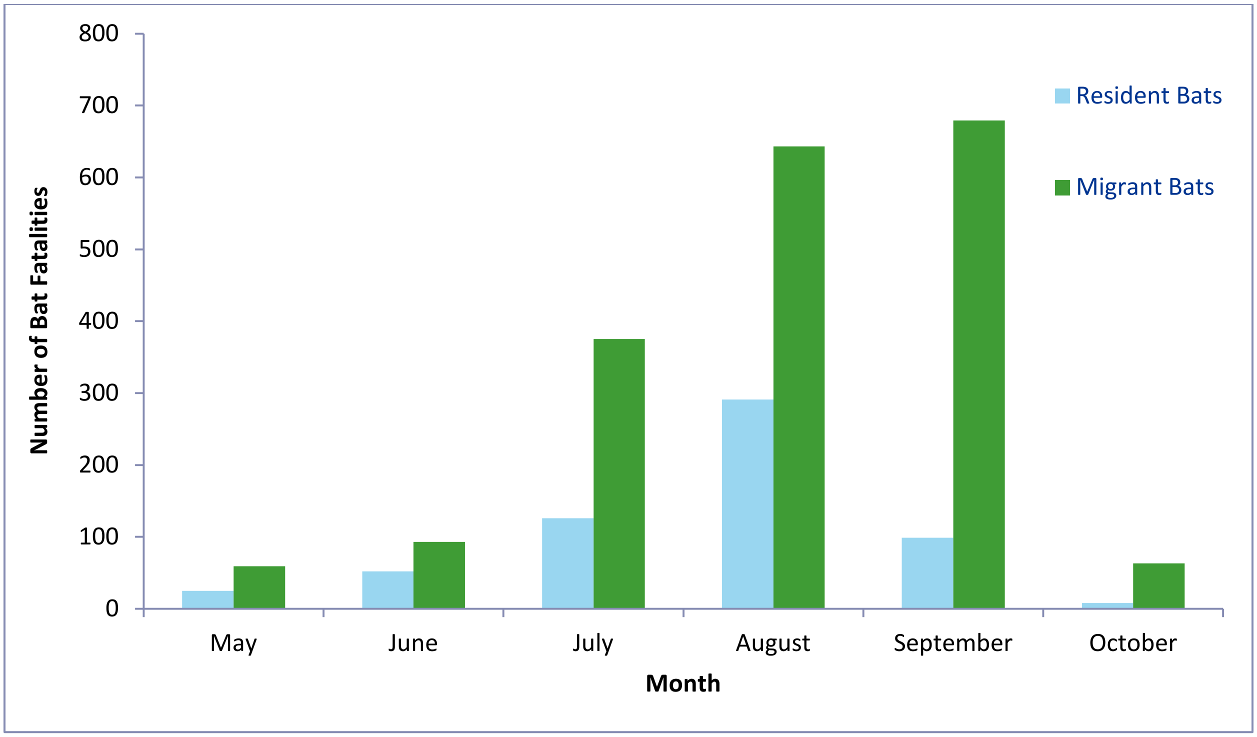
Because the wind industry has provided a diligent and comprehensive record of bat fatalities found at wind energy facilities, seasonal patterns of bat activity can be inferred from these data. In general, bat fatalities documented at wind energy facilities appear to follow seasonal trends corresponding to seasonal bat movement patterns and life cycle phases. Understanding these patterns at individual projects will ultimately help inform appropriate site specific operational strategies so that they are more targeted, efficient and effective. For example, the information available can be used to better-define potential risk periods, effectively reducing risk to bats while potentially narrowing implementation windows at projects using curtailment, with the understanding that the most effective curtailment windows will vary among projects.

To identify the timing and prevalence of bat fatalities from wind turbines in Ontario, the anonymous data collected by NRSI from 2009 to 2015, described above, were examined (NRSI unpublished data; Figure 4-1 and Figure 4-2). Bat fatalities were observed throughout the monitoring period between May and October (inclusive). However, the majority of bat fatalities were observed during the months of July, August, and September (88% of all fatalities), with the highest number of bat fatalities observed in August (n = 934), when 37% of all fatalities occurred. This peak in fatalities corresponds to the anticipated peak periods of summer swarming, juvenile volancy, and fall migration of bats in Ontario and the anticipated seasonal population trends. Again, it is important to note that this dataset includes data prior to and following the introduction and spread of WNS and may not be representative of current species distributions and seasonal patterns.



Source: NRSI Unpublished Data 2009-2015

Figure 4-1. Impacts on Individual Bats due to Wind Turbines in Ontario, Organized by Species.



Source: NRSI unpublished data 2009-2015

Figure 4-2. Seasonal Trends in Fatalities of Resident versus Migrant Bats at Wind Energy Facilities in Ontario.

Anonymous data collected from 2007 to 2015 at 24 wind facilities across Quebec appear to corroborate these findings. During this period, a total of 188 bat fatalities primarily representing three migratory bat species (see Section 4.1.1) were observed throughout the monitoring period (May to October). However, the highest rates were observed during the months of July and August, with a peak in early and mid-August. Similar seasonal patterns have been observed across Canada according to wind energy facility fatality data and other sources (e.g., AB [97], [124]).

In general, resident bats are more localized in distribution, with some species having very limited ranges and inhabiting only a small portion of Canada. Migratory bats that travel from breeding to overwintering habitats typically have wider distributions. Migratory timing (early/late spring arrivals and fall departures) may also vary slightly among species (Appendix A).

4.2 Avoidance and Minimization Options

4.2.1 General Avoidance Measures

General avoidance measures for bats do not affect turbine operations or reduce renewable energy output. These measures, summarized in the bullets below, are designed to reduce the attractiveness of areas near turbines to bats, thereby minimizing the exposure of bats to collision risk, or to minimize the effects of post-construction activities (e.g., retrofits, maintenance activities) on bats. Although effectiveness of these measures is generally accepted, they have not been rigorously evaluated and therefore published studies were not available for review. However, the general principles behind the application of these measures are based on current understanding of bat ecology (Section 2.1) and thus they are typically recommended as best management practices (BMP) by the U.S. Fish and Wildlife Service (USFWS) and other regulatory agencies [125]. As noted in the USFWS Land-Based Wind Energy Guidelines [125], these BMP should be considered organic and will evolve over time as additional learning, experience, monitoring and research becomes available; this learning process will require the input of multiple stakeholders including the wind industry. Note also that the practices provided below may be considered during pre-construction planning, construction and post-construction (including re-powering and decommissioning) phases of a project. General avoidance measures that may be considered include:

- Minimize the number of stormwater control features (e.g., sediment retention ponds) near turbines by eliminating any such features that are unnecessary. This measure minimizes on-site attractants to foraging bats, which often feed on insects attracted to water and also drink from surface water bodies.
- Minimize nighttime work lighting to reduce attractiveness of a project to foraging bats by reducing the attraction of nocturnal insects (but see Section 4.2.3.1). Nighttime work lighting can be minimized by: 1) installing motion activated timed lighting or downward projecting lighting on tower entrances and other facilities, and 2) extinguishing work lights in turbine nacelles at night.
- Conduct any tree removal activities outside the pup season of target species (typically June to July). This will minimize impacts to pups at roosts not yet identified.
- Avoid clearing of suitable spring staging and fall swarming habitat in the vicinity of hibernacula during the staging and swarming seasons (typically early spring and late summer-fall).
- Avoid creating snags or other suitable maternity roosts in the vicinity of turbines.
- Minimize use of pesticides and herbicides during active seasons of bats (i.e., spring through fall).

4.2.2 Curtailment

If fatality levels are observed to be higher than anticipated during the post-construction monitoring program, after consultation with the relevant Provincial agency, curtailment is one potential strategy for minimizing bat collisions. Individual strategies may include:

- feathering turbine blades below manufacturers' default cut-in speeds;
- altering turbine cut-in speeds;
- curtailment during high risk periods based on biological (e.g., migrations) or environmental (e.g., temperature) conditions (i.e. "smart curtailment"); or
- a combination of these approaches.

The literature is limited insofar as publicly available studies evaluating the effectiveness of curtailment, and only two have been conducted at projects in Canada [126], [127]. This section provides an in-depth review of those studies to provide readers with information regarding the use of curtailment as an avoidance and minimization option. In some cases, curtailment strategies are targeted at specific turbines rather than taking a facility-wide approach, based on evidence that all turbines do not pose equal risk to bats and that fatality risk may vary based on individual turbine location [72], [128], [129].

Research demonstrating the effectiveness of curtailment methods to reduce bat fatalities [39] has resulted in industry-led voluntary [130] and agency-directed [88], [131], [132] operational practices. Findings from studies to evaluate the effectiveness of various curtailment strategies are synthesized below; study details are provided in Appendix F. It is important to acknowledge that while curtailment is currently the most commonly employed operational avoidance measure, it is evident that there is no single "blanket" mitigation strategy that has been shown to be effective for all wind farms and all species [133]. The development of alternative mitigation strategies that are tailored to specific wind farms with specific characteristics and species will be important as the number of facilities in Canada increases, and should ideally be incorporated within an adaptive management strategy to further improve effectiveness (See Section 6).

4.2.2.1 Feathering vs. Free-wheeling Below Manufacturer's Cut-in Speed

Feathering turbine blades when wind speeds are below manufacturer's cut-in speed to reduce bat fatalities has been identified as a BMP for wind energy facilities [130]. During curtailment procedures, turbine blades can either be feathered or allowed to free-wheel (i.e., rotate freely) when not producing renewable energy. Turbine brakes may also be applied to fully prevent rotation, but this method carries significant risk of turbine damage and unsafe operating conditions if implemented outside of emergency circumstances and will not be discussed further. Feathering entails adjusting the angle of the rotor blade (typically pitched at an 80 to 90° angle when feathered) so that it is parallel to the wind; this slows the rotation of the turbine, usually to below 2 rotations per minute (RPM) or stops blade rotation completely [39], [134]. During free-wheeling, a turbine does not produce electricity but may still rotate at high speeds up to 10 RPM (approximately 120 to 160 km/hr blade tip speed), which may be lethal to bats [39], [135]. Feathering below manufacturer's cut-in is commonly implemented as a BMP because evidence shows most bats are more likely to be active during periods of low wind speed (e.g., < 3 m/s) than during periods of high wind speed [136]. Therefore, modification of how turbines operate at wind speeds below the cut-in speed may have an impact on fatality risk to bats. The cut-in speed of a wind turbine generator is the wind speed at which the generator is connected to the grid and producing electricity; manufacturers' set cut-in speed ranges between 2.0 and 4.0 m/s for most contemporary turbines [39]. These modifications also may reduce turbine energy output and introduce a longer period of re-cut-in, because the yaw (i.e., the component responsible for the orientation of the wind turbine rotor towards the wind) cannot react instantaneously returning to a wind-facing configuration.

Although studies comparing the effects of blade feathering vs. free-wheeling on bats are limited, results from those that have been conducted indicate that blade feathering below manufacturer's cut-in speed is the more effective method for reducing bat fatalities compared to allowing blades to free-wheel. Studies which examined feathering vs. free-wheeling at cut-in speeds of 3.5 and 4.0 m/s reported statistically significant decrease in fatalities at the feathered turbines ranging from 36–58% when compared to control turbines [39], [72], [126], [137], [138]. Detailed summaries of these studies and analyses are provided in Appendix F. Subsequently, curtailment studies examining the effect of raising cut-in speeds have typically included blade-feathering.

4.2.2.2 Curtailment above Manufacturer's Cut-in Speed

Curtailment at wind speeds above manufacturers' recommended cut-in speeds has been proposed as an effective measure for reducing fatality risk to bats [3], [4], [39], [94]. Curtailment is currently the most commonly-recommended minimization measure by regulatory agencies and has led to a growing body of research aimed at defining appropriate triggers (e.g., wind speed, temperature) and identifying the conditions under which adjusting curtailment triggers is most effective. Published results from curtailment studies were reviewed to assess evidence of effectiveness in reducing bat fatalities across varied conditions (e.g., project size, region, curtailment parameters [temporal window, cut-in speed]). Only studies with a scientific basis (i.e., study design included controls or other form of baseline fatality data) for comparing fatality levels under minimization plans to those when minimization was not in effect were reviewed. A detailed discussion of each study design and findings are available in Appendix F.

Several studies which examined the effectiveness of implementing turbine curtailment at varying wind speeds (from 4.0–6.9 m/s) have been conducted at operational facilities [39], [72], [140], [141], [126]–[129], [134], [137]–[139]. Most published studies have been conducted in the Eastern and Midwestern regions of the U.S. with a few conducted in the Pacific Southwest (Table 4-2). Five of the studies available for review were conducted at facilities in Canada (e.g., [126], [127]). Based on discussions with industry professionals, it is also apparent that due to regulatory constraints in most provincial jurisdictions in Canada, wind energy facilities are often not permitted to conduct experiments with various wind speed cut-ins; thereby restricting progress in understanding how various cut-in speeds can reduce bat impacts. Also, although multiple Canadian projects are known to be operating under curtailment regimes, particularly in Ontario (at 5.5 m/s cut-in), results of these operational measures with respect to fatality reductions are not publicly available for most projects.

Results indicated that reductions in bat fatalities across projects ranged from 9–96%, although many of these reductions were not reported to be statistically significant (Appendix F). Statistical tests are the way that true experimental effects are separated from apparent or indicative effects that may not be real; therefore non-significant results were considered to be indicative but not conclusive in this review. Reductions in bat fatalities were observed at facilities with cut-in speeds of 4.5 m/s or greater (4.5 m/s: 47-77%; 5.0 m/s: 33–87%; 5.5 m/s: 60–96%; 6.5 m/s: 74–78%; and 6.9 m/s: 73–89%; Table 4-2, Figure 4-3); however, the value of raising cut-in speeds above 4.5 m/s remains unclear due to the wide range in results and overlap in findings among the different approaches (i.e. lack of statistically significant differences in measured effects).

Results from studies that directly examined differences between turbines operating at cut-in speeds of 5.0 and those operating at higher cut-in speeds (i.e. 5.0 m/s compared to 6.5 m/s; [128], [129], [139]) have also been mixed, with one study demonstrating significant improvement in fatality reductions [129] and two studies finding no significant difference between the two treatments [128], [139]. The value, if any, of raising cut in speeds above 6.5 m/s is especially unclear as statistical analyses were not performed for the single 6.9 m/s cut-in speed study available for review. Finally, caution should be exercised when comparing results among these various studies, as the results presented have not undergone a formal meta-analysis and differ substantially in several aspects including curtailment timing, method of fatality estimation, and analytical methods, and are not presented with individual study variance measures.

Table 4-2 Curtailment Studies Summary[a]

Cut-In Speed	Effectiveness (approximate mean bat fatality reduction %)[b]	Number of studies with significant fatality reductions	Number of studies with non-significant or untested fatality reductions[c]	Evidence for Effectiveness[d]	Species[e]	Study Region(s)	Reference(s)
4.0 m/s[f]	9-72	1	0	Moderate	LABO, LACI, LANO, EPFU, PESU	Eastern and Pacific Southwest U.S., Alberta	[39]
4.5 m/s	47-77	3[g]	1	Moderate	LABO, LACI, LANO, EPFU, PESU	Eastern and Midwestern U.S., Ontario	[39], [72], [127], [142]
5.0 m/s	33-87	3[h]	3[h]	Moderate	LABO, LACI, LANO, EPFU, PESU, MYSO	Eastern, Midwestern, and Pacific Southwest U.S.	[39], [128], [129], [134], [139]
5.5 m/s	60-96	5[i]	1	Moderate	LABO, LACI, LANO, EPFU	Midwestern U.S., Ontario, and Alberta	[39], [72], [126], [127], [143]–[145]
6.0 m/s	30-60	1	2	Low	TABR, LANO, LACI	Eastern and Pacific Southwest U.S.	[39], [140]
6.5 m/s	74-78	2	2[j]	Moderate	LABO, LACI, LANO	Eastern and Midwestern U.S.	[128], [129], [139]
6.9 m/s	73-89	0	1[k]	Low	LABO, LACI, LANO, PESU	Eastern U.S.	[141]

[a] For full study descriptions and results, see Appendix F.

[b] Effectiveness (fatality reductions as compared to turbines operating at manufacturers recommended cut-in speed) reported by individual studies or back-calculated from reported mean fatalities/turbine. More precise estimates provided in Appendix F.

[c] Studies that reported either non-significant fatality reductions or did not test for significance against controls.

[d] Strength of evidence of effectiveness for reducing bat fatalities based on number of studies and results observed: Low (statistical evidence for effectiveness weak or inconclusive); Moderate (findings mixed but 50% or more studies demonstrating effectiveness). Low strength of evidence for cut-in speeds >5.5 m/s is primarily driven by the fact that few statistically robust studies have been conducted.

[e] LABO = eastern red bat; LACI = hoary bat; LANO = silver-haired bat; TABR = Brazilian free-tailed bat; EPFU = big brown bat; PESU = tri-colored bat; MYSO = Indiana bat.

[f] Experiments at this speed involved feathering of the blades vs. allowing blades to free-wheel.

[g] Includes results from one study reported as significant at alpha level of 0.10.

[h] Includes results from one study comparing fatality rates to those observed in a previous year [134].

[i] Statistics not explicitly reported for one study; effect was assumed to be significant at P < 0.05 based on 96% fatality reduction [145].
[j] Includes two studies for which only pooled results from multiple curtailment thresholds (5.0 m/s, 6.5 m/s) were analysed and found to be significant; unclear if individual threshold produced significant results [128].
[k] Compared results to fatality rates at other North American, Northeastern U.S., West Virginia projects [141].

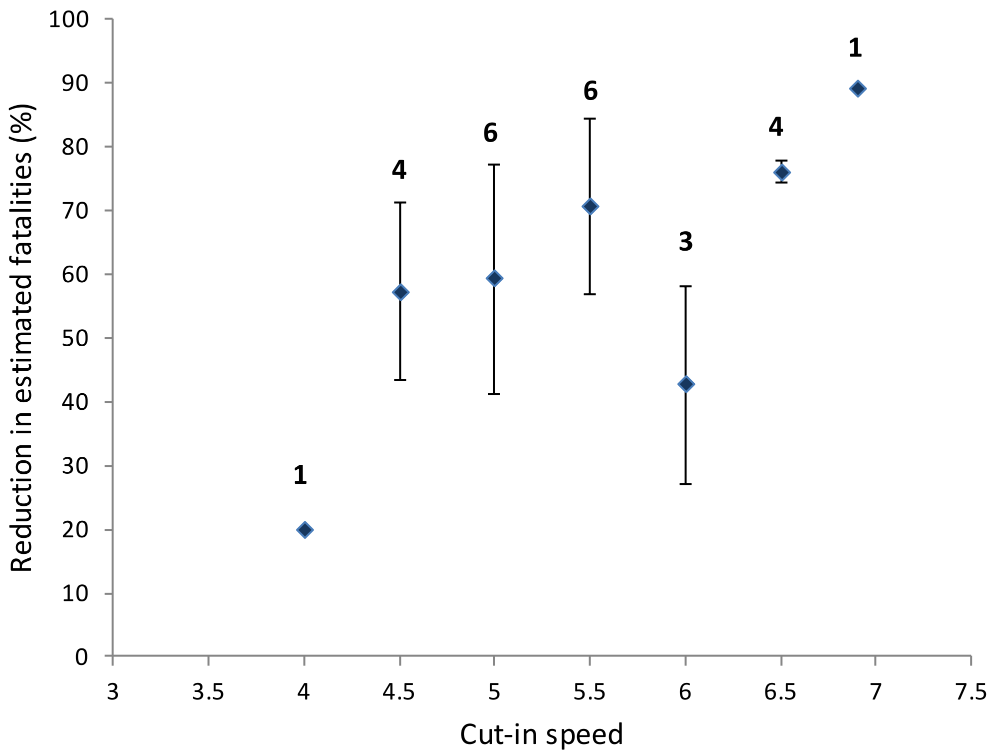


Figure 4-3. Reported fatality reductions (compared to operated controls, prior years [134] or local comparable projects [141]) from curtailment assessments of increased cut-in speeds. Mean (SD) fatality reduction rates were highly variable among studies. Numbers above standard deviation bars refer to sample size (number of studies) for a given cut-in speed. Note that standard deviation bars represent variability among the mean reductions reported and do not incorporate within-study variance (available in Appendix F).

4.2.2.3 Operational Impacts Associated with Curtailment

Wind turbine curtailment can have impacts on the operational nature of wind energy projects. These impacts come in the form of lost generation during the curtailment period and accelerated turbine deterioration or damage caused by altering the normal operating parameters of the turbines specified by manufacturers.

Lost generation at an individual wind project is based on a variety of factors, and cannot feasibly be standardized or predicted for all projects across the industry. Currently, only two publicly available reports have attempted to report lost generation associated with curtailment, although since the wind generation profile at these projects is unique, the results cannot be fully assessed relative to other operating wind projects in Canada or the U.S. [126], [128]. To develop a more general understanding of the impacts on generation from curtailment, several wind energy producers in Canada were interviewed during preparation of this document. Responses indicated that lost generation was highly variable, depended on turbine type and annual wind profile, and under some conditions and implementation parameters were identified as significantly affecting project sustainability. In general, the impacts of curtailment on power generation are most pronounced when average wind speeds are low (in the range of curtailment), or if annual wind profiles peak during the curtailment period. Energy loss as well as impacts on equipment could potentially be reduced by altering curtailment trigger parameters, while still reducing bat fatalities; for example, the effects of increasing temporal windows for calculating average wind speeds from six-minute to ten-minute intervals deserves further study. This or similar approaches may present opportunity for balancing power and conservation needs. Smart curtailment, or the use of acoustic monitoring or other methods to trigger curtailment when bat activity is high, may also refine curtailment periods to be more effective while reducing loss of energy production (Section 4.2.3.2).

Lost production that occurs as a result of curtailment will likely lead to requirements for supplementing the grid with fossil fuel production and subsequent increased environmental costs. There is therefore a critical need to better understand the implications of curtailment on project sustainability/economics and climate objectives, as well as to identify the degree of effectiveness of curtailment measures. With respect to climate objectives, an interagency group convened by the Whitehouse in the U.S. recently estimated the average economic damages associated with the release of each metric ton of carbon dioxide into the atmosphere (i.e., social cost of carbon) as ranging from $11 to $56 (USD) for a release in 2015, depending on the discounting assumed over time [146]. Thus, the loss of carbon offsets due to curtailment has real, quantifiable costs for society. Specifically, the increased burning of fossil fuels to meet energy demands may result in societal costs as a function of various factors including changes in agricultural production, human health consequences, property damages and energy system costs [146]. It is therefore prudent to explore alternative means of minimizing impacts to bats, while maximizing clean energy production.

4.2.3 Emerging Technology

A variety of technological approaches to reduce risk to bats from wind energy facilities during operations may be considered; many of these options are currently under development, but are not yet ready for commercial deployment. These emerging technologies can be broadly categorized into three general categories: deterrent devices, detection and monitoring devices, and integrated monitoring and minimization systems. This chapter provides a broad overview of the most promising types of devices within each category, describes the goals and methods of each approach, and suggests criteria for evaluating their applicability and effectiveness for application to a wind energy facility. Detailed discussion of individual categories, including examples of models being tested and/or marketed in each category, are provided in Appendix G.

Risk to bats may be avoided or minimized by deterring bats from entering rotor-swept areas (RSAs; i.e. the area of circle swept by the blades of an individual turbine) during operations, or by employing minimization measures when bats are at risk of entering RSAs. Monitoring technology during operations is aimed at determining effectiveness of minimization measures and/or informing targeted minimization measures. Technological advancements have therefore focused on developing or improving methodologies aimed at these objectives. In assessing the utility of the three categories of emerging technologies, it is important that potential users consider several factors:

(1) What is the ecological basis for the expected effectiveness of the technology for reducing risk to bats?;
(2) How much testing has been conducted to assess the technology’s functionality and compatibility with turbine operations, and what have results shown thus far?;
(3) Have laboratory and field results demonstrated effectiveness for influencing bat behaviour or for reducing risk to bats?;

(4) How close to commercial readiness is the technology?; and
(5) What other considerations may need to be explored or addressed?

Other considerations may include biological uncertainties or questions about compatibility with current industry processes (see Appendix G). The emerging technologies presented in this chapter are primarily in the early stages of development and testing, so specific considerations identified in Appendix G are difficult to assess as most have not been explicitly tested or reported; however, related factors (e.g., species tested, power source) are addressed where applicable. It is the goal of this chapter to provide the best available information to date in order to inform industry decisions as they pertain to use of these, or similar devices. The information presented here is also intended to facilitate discussions and partnerships among industry, agency, and non-governmental organization (NGO) stakeholders to support further research on these and other devices, with the goal of identifying effective and technologically feasible methods and advancing broader deployment of these methods.

4.2.3.1 Deterrents

Various deterrent methods are currently in the development and testing phases, with the aim of reducing bat fatalities at wind energy facilities or other exclusion areas. Advancements in this area generally assume that fatalities can be decreased by influencing bat behaviour; for instance, discouraging bats from approaching individual turbines or decreasing bat use of a project site. The goal of deterrent usage is to effectively reduce production loss compared to curtailment while continuing to minimize risk to bats. Emerging deterrent technologies are based on current knowledge of the sensory ecology, behaviour, and susceptibility of bats to collision risk and in some cases on preliminary findings from earlier prototypes [136], [147]–[150].

Several potential methods for deterring bats have been suggested for use at wind energy facilities based on observed bat reactions to acoustic, surface coating, lighting, and electromagnetic radiation stimuli. Sections below provide summaries of published findings with respect to bat behavioural responses and field observations of bat responses to each class of potential deterrent. A more detailed assessment of specific deterrent methods and models under development and testing is provided in Appendix G. It is important to note that in most cases, technological approaches to deterring bats have not yet undergone complete effectiveness testing and are not yet practicable for widespread use. Initial tests, however, suggest that some of these technological solutions are likely to be effective at minimizing risks to bats. Those that demonstrate effectiveness for reducing risk to bats will likely be commercially available within the next five years. The wind industry continues to work cooperatively with regulatory agencies, developers, and academics to accelerate the identification and commercialization of effective bat deterrent measures.

Acoustic Deterrents

Insectivorous bats rely heavily on acoustic signals, using echolocation through the production of high-frequency ultrasonic (i.e., > 20 kilohertz (kHz)) pulses of sound to navigate, orient and hunt [151]. Bats are able to hear frequencies ranging from approximately 8 kHz to 200 kHz [152]; Canadian species echolocate in the 20 to 120 kHz range [153], with characteristic frequencies (i.e., the frequency at which time and energy is primarily allocated) in the 20 to 55 kHz range. Bats typically emit pulses at approximately 110 decibel (dB), with returning signals, or echoes, significantly lower in intensity than the original signal [154]. They tend to modulate the frequency of their calls from high to low, and can adjust frequency based on acoustic, social, or foraging conditions [152]. There is some evidence that species with the highest turbine collision risk tend to emit high-intensity, short-pulse, echolocation calls within a narrow frequency-band (typically wide-ranging species that forage in open habitats; [155]), although the process by which these characteristics may increase risk is currently unknown. The distances from which bats are able to receive signals from large structures during echolocation are unknown and vary by species, but it has been suggested that the maximum range is approximately 20 to 40 feet, which is shorter than the length of commercial-scale turbine blades [156] (i.e., bats do not "detect" turbines until they are within the RSZ).

Recent findings have suggested that bats can perceive high frequency sounds returning from turbines if they are received at high enough amplitudes [150], [157]. Rather than acting as an attractant, however, it has been suggested that such high-amplitude ultrasonic sounds could effectively jam the echolocation and communication abilities of bats by masking returning signals (i.e. echoed signals from objects, conspecific calls) [150], [157] if the sounds reach bats at appropriate amplitudes. Bats do tend to avoid noisy environments, particularly when feeding [158]–[160], although the processes behind the avoidance are not fully understood. Bats have also evolved to negatively respond to toxic moths based on ultrasonic warning clicks, and the clicks of some moth species may have evolved to jam bat echolocation signals [161], [162]. Some bat species may also use jamming signals to compete with foraging conspecifics (i.e., reduce the attractiveness of a foraging space to bats of the same species) [163]. It is based on this growing body of knowledge that the potential use of acoustic deterrents has gained increased interest in recent years.

Development and testing of several high-intensity, broadband ultrasonic noise deterrents has been initiated over the last decade, with the objective of making targeted areas less attractive to bats, either by jamming echolocation and communication pathways and/or creating generally unpleasant short-term conditions that might be perceived by bats as risky (e.g., predation or collision risk). Bat activity typically resumes soon after a deterrent is removed or turned off [164]. Potential deterrent technology options are in various stages of development and have undergone disparate levels of effectiveness testing, including tests in laboratory, field, and operational wind facility settings (see Appendix G for study details). Although to date no acoustic deterrent device has been successfully commercialized [165], several new devices are in the development and testing phases and a subset of these are considered near-commercial (i.e., not currently available for purchase but undergoing field testing and/or pilot deployments; see Appendix G). Published findings regarding acoustic deterrents are limited but have revealed effects on bat behaviour and, in some cases, bat fatality rates (Table 4-3). Limitations to the devices summarized in Table 4-3 are primarily related to attenuation, or the rapid reduction in amplitude as ultrasonic sound moves away from the emission source. Additionally, initial testing indicates that some species do not consistently appear to be deterred by available ultrasonic devices as currently configured [166], [167]. A primary concern about the effectiveness of these devices is thus that the sounds emitted do not provide coverage of the entire RSZ. Attenuation may be addressed by increasing the power of the original transmission (Sound Pressure Level [SPL]), and several of the newer devices incorporate increased SPL capability, whereas others are blade-mounted in order to provide coverage outside the RSZ. Results have thus far been promising, and indicate that as acoustic technology is further developed these devices may offer effective options for the wind energy industry to reduce risk to bats during operations.

Overall, findings to date indicate that acoustic deterrents hold promise, particularly if limitations caused by the rapid attenuation of ultrasonic sound can be addressed; however, their practicability is yet to be demonstrated. Some studies suggest that bats may be more likely to approach turbines from specific directions (e.g., leeward side) [136] and additional research regarding optimal device placement is ongoing. Also, because some concern has arisen over the possibility that acoustics could disorient bats and potentially make them more susceptible to strikes [164], [168] further research is needed to evaluate the effectiveness of deterrents at reducing fatalities. The wind energy industry, regulatory agencies, developers, and researchers can continue to work cooperatively to accelerate the identification and commercialization of effective bat deterrent measures.

Table 4-3 Acoustic Deterrent Results Summary[a]

Year	Study Type	Location	Study Site Type	Freq. Range (kHz)	dB SPL[b]	Device Description	Results (vs. Controls)	Considerations		Reference(s)
								Species[c]	Environmental	
2006	Lab	Maryland	Lab	12.5-112.5	100 (per speaker at 1 m)	Prototype 8-speaker, white noise	**Significant Reduction in Bat Activity**: Reduced activity during feeding (*P* < 0.004) and non-feeding (*P* < 0.02) trials.	EPFU	N/A	[157]
2006-2007	Field	California, Oregon, Arizona	Ponds	20-80	~120 (per speaker at 1 m)	8-speaker, white noise	**Significant Reduction in Bat Activity:** Year 1, significant reduction in mean baseline activity[d] ($P \leq 0.025$). Year 2, significant reduction in median activity rate[e] ($P = 0.0001$).	PAHE and other unidentified species	Monitored bat activity and behaviour with ultrasonic emissions when temperature was >10 °C, wind speed <2.25 m/s, and when no precipitation was expected.	[169], [170]

Table 4-3 Acoustic Deterrent Results Summary[a]

Year	Study Type	Location	Study Site Type	Freq. Range (kHz)	dB SPL[b]	Device Description	Results (vs. Controls)	Considerations		Reference(s)
								Species[c]	Environmental	
2007	Field	New York	Turbines	20-80	119	3 emitter arrays, pulsed sounds	**Mixed Results – Bat Activity**: Significant difference between bat activity at control and treatment sites (P = 0.026) in first, but not second trial (P = 0.97).	Primarily tree-roosting bats	Pre-existing site differences (e.g., habitat types, proximity to roosts) may have influenced results. As barometric pressure increased there was a slight decrease in bat activity during the study.	[168]
2009	Field	West Virginia	Ponds	26-74	105	Black and Decker, Model EX900-A	**Significant Reduction in Bat Activity:** Mean number of nightly bat passes significantly lower than when deterrents not deployed (P < 0.001).	Not reported	Found weather did not play a significant role in bat activity reductions (however, one-week study only).	[171]

Table 4-3 Acoustic Deterrent Results Summary[a]

Year	Study Type	Location	Study Site Type	Freq. Range (kHz)	dB SPL[b]	Device Description	Results (vs. Controls)	Considerations		Reference(s)
								Species[c]	Environmental	
2009-2010	Field	Pennsylvania	Turbines	20-100	≥ 65	Waterproof box, housing 16 transducers/emitters	**Mixed Results – Bat Fatalities:** 0-64% fewer bats killed at treatment turbines than at control.	EPFU, LABO, LACI, MYLU, LANO, PESU	Rapid attenuation of sound, especially in humid environments.	[150]
2013	Field	Hawaii	Plantation	20-100	≥ 65	Waterproof box, housing 16 transducers/emitters	**Significant Reduction in Bat Activity:** Mean number of bat passes reduced by more than 85%.	LACS	N/A	[164]

[a] Studies represent only those with published, peer-reviewed results. See Appendix G for a detailed discussion of deterrent technologies that are currently in development and testing, including unpublished results as of fall 2016.

[b] Decibel (dB) and Sound Pressure Level (SPL).

[c] EPFU = big brown bat; PAHE = western pipistrelle; LABO = eastern red bat; LACI = hoary bat; MYLU = little brown myotis; LANO = silver-haired bat; PESU = tri-colored bat; LACS = Hawaiian hoary bat.

[d] Number of bat passes.

[e] Bat passage rate per hour.

Tower Surface Coatings

A limited number of studies have suggested that turbine tower surfaces may play a role in potential bat attraction to wind turbines. For instance, one study from the United Kingdom suggested that insects are attracted to white and light grey surfaces and tend to concentrate at higher densities around turbine towers with standard white or light grey coating, thus potentially attracting bats [172]. Bats have been observed foraging around turbines, particularly during migration [5], but the extent to which turbine surface color results in higher risk to bats remains unstudied. A second possibility is that bats are attracted to turbine towers as a result of turbine towers reflecting sound profiles similar to water or other smooth surfaces. Echolocation signals returning from turbines could thus directly signal a water source or indicate a smooth surface that could facilitate prey recognition [173]–[178], because bats may perceive changes in the depth profile of insect prey items against smooth surfaces as an "acoustic shadow," or disruption to the flat, smooth surface of water, leaves, or turbine towers [178]. Bats have been observed investigating turbine towers at operational facilities for potential foraging purposes [168] and showing foraging behaviours at turbine models in a laboratory setting; they also appear to be less attracted to rough, texturized surfaces, indicating that texturized surface coatings may hold promise as an effective deterrent method to reduce bat activity in the vicinity of the turbine towers (see Appendix G). Additional research is required however to assess the effectiveness of different coatings and to ensure that any surfaces applied do not inadvertently act as attractants (e.g., by mimicking tree bark and thus potential roost sites; [173]). In addition, retrofitting existing turbines may not be practical for all projects due to financial or environmental factors; however, there could be opportunity to incorporate alternative coatings to turbine towers into the turbine manufacturing phase.

Lighting

Although greater attention has been given to reducing bat fatalities at wind energy facilities using acoustic methods, it is known that most bat species also rely on visual information [179]. Bats may ignore acoustic signals when visual information is present, and appear to use visual cues to improve success in locating mates, identifying roost trees, detecting predators, or hunting when moths and other insects aggregate at lights (review in [179]). Vision may be particularly important to bats for long-distance movements because they are typically unable to detect echoes from their calls at distances greater than 20 m [153].

The fact that wind energy facilities are required to use flashing red lights as obstruction lighting for aircraft [180] initially resulted in concerns about the potential for aviation lighting to attract bats and increase collision risk [149]. Moths and other insects are known to occur at high densities near lights, which could potentially attract bats to turbines and other lighted areas [181]. Studies have shown, however, that bat fatalities do not increase at turbines with flashing red lights when compared to turbines without lighting [4], [182], [183] and that these flashing red lights may actually reduce fatalities for some species [183]. Still, concerns remain about the potential for lighting to disorient bats [184], [185], and the wind industry is also facing new federal lighting requirements which require CL-864 medium-intensity lighting on multiple turbines; the potential for bat reaction to these new measures is unclear.

Research is ongoing to increase understanding of bat response to visual stimuli at wind energy facilities, including explorations of the potential use of lighting to deter bats from operational facilities.

Bats tend to aggregate at tall structures [148], potentially because these structures mimic trees (i.e., roosting or foraging sites), and it has been suggested that supplemental lighting of turbines may decrease the likelihood that bats could mistake them for trees, thereby reducing collision risk [136], [185]. Dim ultraviolet (UV) lighting in particular has recently emerged as a potential method to avoid and minimize bat fatalities without causing safety or disturbance concerns (see Appendix G). Dim UV methods are still in the initial testing phases, has produced variable results, and more research will be necessary in this area to evaluate the potential effectiveness of using UV lighting as an avoidance and minimization tool. Concerns that UV lighting devices may increase insect activity are also being explored.

Electromagnetic Radiation

Studies in Scotland have indicated that the electromagnetic fields from military air traffic control radar stations [186] and small, portable fixed-antenna radar units [187] may reduce bat activity during foraging. Researchers measured bat and insect activity and found that medium pulse rates (0.3 μs) were more effective at reducing bat activity than short pulse rates (0.08 μs) and electromagnetic field strengths of > 2 volts (v)/m had the strongest deterrent effect [186]. Insect density was not affected by the radar signals, thus eliminating deterrence of insects as a likely basis for the effect on bats [186], [187]. Hypotheses for why bats avoid electromagnetic fields include that the radiation may cause bats to overheat (i.e., via hyperthermia), or that the radio frequencies emitted by radar (3 to 300 kHz) may interfere with echolocation activities such as those used for hunting and navigating [186], with more support for the latter [187]. Radar has not been tested as a potential bat deterrent at wind energy facilities, however, and the method may not be as effective for deterring migrating compared to foraging bats. There are also several concerns about the potential negative effects of radar, including that long-term exposure could induce stress in bats [187]. Additionally, radar facilities can be cost-prohibitive for large-scale use, as would be needed to deter bats from a wind energy facility. No recent studies on the potential for using radar as a bat deterrent for wind or other industries have been conducted.

Deterrents Summary

The exploration of using deterrents as possible standalone or supplemental tools in avoiding and minimizing effects on bats continues at a rapid pace and several appear to hold significant promise. Table 4-4 provides a general overview of the demonstrated effectiveness, limitations, and overall considerations associated with the various deterrent technologies currently being developed and tested.

Table 4-4 Deterrents Summary

Deterrent	Potential Effectiveness	Strength of Evidence	Considerations
Acoustic	Moderate	Moderate	• Not fully commercialized but several in development and testing phases. • Cannot be used in concert with acoustic bat activity monitoring. • Current options subject to rapid attenuation and reduced impact area, particularly in humid environments. • Further research is necessary to ensure that acoustics do not attract bats or increase collision risk. • Low to moderate cost[a]; multiple retrofit and mounting options available or in development (i.e., nacelle, tower, blade). • May require regulatory approvals prior to deployment.
Surface coatings	Moderate	Low	• Potential effects of turbine color have not been tested. • Texturized coatings hold promise but in very early stages of development. • Further research is necessary to ensure that coatings do not attract bats or increase collision risk. • Will likely be most effective when used in concert with other deterrent methods. • May not reduce bat activity throughout the RSZ. • May be most effective for foraging bats. • Low to moderate cost[a]; can be retrofitted but most economical when applied during turbine construction.
Lighting	Low-Moderate	Low	• Concerns about effects on aviation safety, disturbance to humans, and the potential to disorient bats. • Flashing red lights do not appear to affect bat activity or risk. • Dim UV lighting holds some promise but is still in the early testing phase. • UV lighting may increase insect activity. • Further research is necessary to ensure that UV lighting does not attract bats or increase collision risk. • May not be feasible under low-visibility environmental conditions. • Low to moderate cost[a]; would need to be employed at multiple turbines. • May require regulatory approvals prior to deployment.
Electromagnetic radiation	Low	Low	• Several systems are commercially available. • Concerns about negative health effects to bats. • Reduced capabilities under high moisture conditions. • High cost[a]. • May require regulatory approvals prior to deployment.

[a] Deterrent cost categories represent relative estimated costs: Low – relatively inexpensive and installation costs relatively low; Moderate – relatively inexpensive but multiple deterrents likely to be required; High – deterrent units relatively expensive and high cost for implementation and data processing.

4.2.3.2 Detection and Monitoring

Various detection and monitoring methods are employed at wind energy facilities during project siting and operational phases to assess potential risk to bats and identify target species. Acoustic monitoring is the most commonly used monitoring tool, and research and technology have primarily focused on identifying optimal mounting options and improving automated species identification tools. Other detection and monitoring technologies are in the earlier stages of development and testing. The most effective monitoring strategies are likely to consist of multiple monitoring methods contingent upon specific project objectives and conditions. Performance is typically affected by environmental conditions, and some methods (i.e. acoustic) cannot be used in conjunction with deterrents (i.e., acoustic).

Acoustic

Because bats rely heavily on ultrasonic acoustic signals to navigate and hunt, ultrasonic acoustic bat monitoring is a means of detecting bats that may be used to identify risk and potentially inform operational minimization activities. Although acoustic monitoring has been typically been used during pre-construction to identify risk, it is relevant to note that bat activity measured by project-scale acoustic data has not been shown to accurately predict risk of bat fatalities [17], [18], a shortcoming that is apparent for tree-roosting bats as well as cave-roosting bats. Poor prediction rates may be due in part to the fact that acoustic measures of bat activity do not necessarily reflect abundance (i.e., reflect number of bat passes rather than number of individuals). It has also been noted that acoustic monitoring alone may be insufficient to document migratory bats in open habitats (e.g. grasslands, water bodies), as they do not typically echolocate over large open areas during migration [3], [18]. Furthermore, bat activity levels as well as species composition measured at ground level often do not represent conditions within the RSZ [3], [113], [188], and this disparity may be especially true in forested habitats [189]. Recent research, however, indicates that monitoring at nacelle-height may be an effective method for detecting risk [190]; several studies have thus recommended conducting acoustic monitoring from nacelle or blade height when feasible and potentially coupling with other methods, such as radar or IR cameras [191]–[193], to combat some of the challenges associated with acoustic monitoring.

To accompany acoustic and other monitoring technologies, various automated bat detection software programs have been designed to identify bat passes to species level. Such programs often have low detection rates and accuracy of species identification can be inconsistent across species and regions [18]. Experts are generally required for the identification of high-priority species, a key factor in project planning and communication with agencies. Automated bat-identification software is a rapidly developing area, however, with sophisticated extraction methodologies including those based on machine-learning and Evolutionary Neural Networks showing promise [194], [195].

The academic research community interested in wind energy impacts is currently focused on gaining a better understanding of bat behaviour as it relates to altitude and on improving automated species identification; it is expected that this research will continue to improve the overall effectiveness of acoustic monitoring as a tool for predicting collision risk. Several automated detection-curtailment systems have already incorporated acoustic monitoring algorithms into their operations (see Section 4.2.3.3) and will continue to benefit from this research. These systems currently direct most smart-curtailment strategies, which refine curtailment actions according to bat activity, so that they are likely more effective for minimizing risk to bats while reducing power production loss.

Infrared Imaging

The use of IR has recently gained attention as a useful tool for monitoring bat activity at close range. Although IR technology has been studied at wind energy facilities for over a decade [196]–[198], only recently have units been developed that are relatively inexpensive (i.e., < $5,000 USD) and can function effectively under field conditions [136], [199]. New models are also being developed that can record at very low light levels, have increased fields of view, and allow for automated, real-time data processing [199]. One of the primary limitations of IR monitoring in the past has been the inability to discern between birds, insects and bats; however, recent advancements in 2-D and 3-D IR classification algorithms have demonstrated improved accuracy for identifying bats and quantifying bat activity [195], [200]–[203]. For example, by developing a logistic regression classifier based on various "target" characteristics such as size, velocity, heat, and flight-path, researchers were able to discern among birds, bats, and insects with approximately 77% accuracy using 3-D IR data collected at Ottawa National Wildlife Refuge (ONWR), Ohio [200], [201]. When coupled with an acoustic monitoring system as part of an Evolutionary Neural Network (i.e., a machine learning-based monitoring system incorporating supervised [acoustic] and unsupervised [thermal IR] identification algorithms), the ONWR data and those from Toledo National Wildlife Refuge were used to correctly identify bats to species with up to 90% species classification accuracy [195]. Higher rates may still be attainable using manual vetting via call libraries.

More recently, 2-D IR cameras have been proposed as an effective, less expensive bat monitoring tool than 3-D IR cameras, because they do not require two calibrated cameras and data processing is consequently less memory-intensive [203]. Recently developed discriminant models [202] and automated processing methods [203] for analyzing 2-D IR flight path data have shown variable but promising results for identifying passing targets as bats. Preliminary observations indicated that classification could be improved by identifying target distances (e.g., with marine radar [202]). It was also noted that effective automated processing of bat targets may be limited to those passing within 100 m of the camera [203]. Ongoing 2-D IR research is currently focused on identifying configurations and angles to maximize field of view and increase the likelihood of strike detections [204] (see Appendix G).

It is expected that the greatest value of using thermal IR imaging methods will be to provide information about the specific conditions under which collisions occur, when coupled with fatality searches. This information can then be incorporated into predictive collision models to improve the accuracy of predictions and potentially reduce operational costs by more precisely defining risk-periods (see Section 4.2.3.3). Infrared data can also provide valuable information about the close-range interactions of bats with turbines under various scenarios, including those incorporating deterrent or other minimization and avoidance measures. Thermal IR imaging is thus unlikely to serve as a stand-alone monitoring method, but can be a useful complementary data-collection tool to standard acoustic or other monitoring strategies. Limitations to thermal imaging include reduced effectiveness in poor environmental conditions (e.g., high humidity, rain, clouds) and limited sampling area.

Collision Detection

Researchers from Oregon State University, with support from the University of Washington and the Northwest National Marine Renewable Energy Center, designed and conducted preliminary tests of a multi-sensor collision-detection system. The system incorporates contact microphones (wireless) and accelerometers (wireless) to detect impacts with the turbine blades, visual cameras (cabled), IR cameras (cabled), and bioacoustics microphones (cabled) [205], [206]. The system design is intended to detect collisions not only with blades, but with the tower and nacelle of the turbine(s) while also providing identification as a bird or bat. Multiple mounting configurations were examined for the sensors and cameras in the initial laboratory and field testing, which began in 2014. Simulated tests in which tennis balls were fired at wind turbines were initially successful at recording impacts with the turbines and indicated that the system was operable. It was suggested that the contact sensors (microphones and accelerometers) be placed on the blades, with the acknowledgement that they would have to be finely tuned to filter signals from normal vibrations of the blades, as the contact microphones exhibited false positives during simulated tests [205]. The results also indicate that the sensors should be minimized to decrease interference with turbine operation. The system was originally developed to be a multi-faceted detection system for use at offshore wind turbines and no further research of the system has been published. This appears to be the only integrated system that incorporates strike-monitoring technology on which testing has occurred.

Marine Radar

Radar technology has been used for avian and bat monitoring for over a decade and is currently integrated into some Detection-Avoidance systems (Section 4.2.3.3). Marine radar systems typically combine a vertically pointed stationary radar beam with a horizontally pointed stationary radar beam to capture data on “target” (e.g., bird, bat) passes over an area [192]. Radar can provide the distance to a target (horizontal beam), the flight altitude of a target (vertical beam), and has a greater range (i.e., 1 to 4 km for birds at offshore sites [207]; range is less clear for bats) than other monitoring methods (e.g., acoustic, IR) [202]. Marine radar is generally more expensive to operate and radar data processing is more complex and expensive than for acoustic or IR monitoring technologies [202]. Noise and clutter in radar data makes it difficult to identify targets under some conditions [208], clutter may occur from the turbines themselves [202], and radar cannot typically identify targets to species level or differentiate between birds and bats [209], [210]. However, new systems and associated interpretation and processing software (e.g., [211]) continue to improve data processing and noise and clutter removal and are continually being evaluated for effectiveness of detecting bats. Some new systems are also utilizing multiple technologies by combining marine radar with other monitoring and detection methods, such as acoustic detectors [212].

Detection and Monitoring Summary

A summary of the primary detection and monitoring technologies that are either currently used, or being considered for use, at operational wind energy projects is provided in Table 4-5. Some of these methods are also used during pre-construction planning but a full discussion of their utility for this purpose is beyond the scope of this document. The general benefits, limitations, status and considerations associated with each technology type are addressed.

Table 4-5 Detection and Monitoring Technologies: Overview and Status

Technology	Benefits	Limitations	Technology Status		Considerations		
			Lab Tested	Field Tested	Commercial Availability	Species[a]	Environmental Conditions
Acoustic Monitoring Systems and Automated Bat-identification Software	• Effectiveness increased when coupled with IR imaging or marine radar. • Many commercially available options. • Emerging algorithms showing promise for automated classification. • Bat-identification software rapidly improving.	• Currently available identification software is inconsistent and requires quality control. • Periodic visits by a technician needed to obtain data and check equipment. • Bat experts still generally required for identification of high-priority species. • Cannot be used in conjunction with acoustic deterrents. • Often used to collect ground level data that do not correlate with blade-level activity. • Limited sampling area (< 30 to 40 m).	Yes	Yes	Several acoustic monitoring systems commercially available and integrated into some detection and avoidance systems (see Section 4.2.3.3).	Current bat identification software is multi-specific and not limiting.	When coupled with marine radar: reduced capabilities under high moisture conditions.

Table 4-5 Detection and Monitoring Technologies: Overview and Status

Technology	Benefits	Limitations	Technology Status		Considerations		
			Lab Tested	Field Tested	Commercial Availability	Species[a]	Environmental Conditions
Thermal IR Imaging and Bat-identification Software	• Unit costs have been decreasing to levels that may not be cost prohibitive in larger applications. • Can identify timing of strikes. • Can assess close-range behaviour of species. • Models being developed that can record at very low light levels, have increased fields of view, and allow for automate, real-time data processing. • Recent advancements in algorithms demonstrate improved accuracy for detecting and quantifying bats. • Identification capabilities may be increased when coupled with marine radar or acoustic detectors.	• Insufficient as a stand-alone monitoring tool. • Limited sampling area (< 100 m). • Current automated processing systems appear to be more efficient at detecting birds than bats. • More effective when coupled with acoustic or radar.	Yes	Yes, with limited studies at operational wind turbine sites.	Several IR systems commercially available and integrated into some detection and avoidance systems that are commercially available (see Section 4.2.3.3).	LANO, NYHU, LACI, EPFU, PESU, LABO, MYLU[b]	Reduced effectiveness in poor environmental conditions (e.g., high humidity, rain, clouds). When coupled with marine radar: reduced capabilities under high moisture conditions.

Table 4-5 Detection and Monitoring Technologies: Overview and Status

Technology	Benefits	Limitations	Technology Status		Considerations		
			Lab Tested	Field Tested	Commercial Availability	Species[a]	Environmental Conditions
Collision Detection / Multi-sensor System	• Incorporates blade-impact technology. • Can typically discriminate bats from birds.	• Preliminary studies only, effectiveness studies yet to be conducted.	Yes	Yes, but still in preliminary testing.	No, still in testing.	Cameras and acoustic sensors can detect multiple species.	May be most beneficial for offshore facilities, facilities in remote regions, or other facilities for which fatality data are unattainable or expensive to collect.
Marine radar monitoring systems	• Can provide distance to target and target altitude. • Greater range than other detection and monitoring methods. • Interpretation and processing software improving. • Identification capabilities may be increased when coupled with IR imaging or acoustic detectors.	• Noise and clutter makes it difficult to identify specific targets. • Cannot differentiate between birds and bats. • High monitoring and processing costs.	No	Yes	Commercially available. Some marine radar systems integrated into detection and avoidance systems that are commercially available (see Section 4.2.3.3).	Does not identify radar targets to species. Can be coupled with acoustic monitoring to identify species present (see Appendix G).	Reduced capabilities under high moisture conditions. Susceptible to signal scatter from landscape features (e.g., buildings, hills) and may be difficult to site.

[a] LANO = silver-haired bat; NYHU = evening bat; LACI = hoary bat; EPFU = big brown bat; PESU = tri-colored bat; LABO = eastern red bat; MYLU = little brown myotis.

[b] Species composition as identified at ONWR and Toledo National Wildlife Refuge using acoustic and thermal IR imaging detection.

4.2.3.3 Integrated Detection-Deterrent and Avoidance Systems

An increased understanding of bird and bat collisions with wind turbines, combined with technological advancements, has presented the opportunity to combine monitoring systems with deterrent or avoidance systems. The objective of integrated systems is to monitor bat activity and/or perceived risk at a project or specific turbine, and implement operational or deterrent measures based on automated feedback. Although several systems are commercially available, publicized results evaluating the effectiveness of these devices are limited. Most integrated systems include communication with operational Supervisory Control and Data Acquisition (SCADA) systems, so compatibility should be considered (Table 4-5), along with any mounting or functionality factors associated with the individual monitoring device(s) (Appendix G) integrated in the system.

Integrated detection-deterrent systems have shown some promise for keeping birds from unwanted areas [213], [214]; however, they are unlikely to be effective for bats because bat activity resumes soon after a deterrent is removed or turned off [164]. Detection-deterrent systems may also be impractical for bats if they promote movement in and out of a project area and potentially increase strike risk. To date no studies have examined the effects of detection-deterrent systems on bats.

Although various integrated detection-avoidance systems are available and in use worldwide for birds and bats, particularly for offshore projects, none have been extensively tested for effectiveness in reducing risk to bats. Appendix G provides more detailed descriptions of a non-inclusive sample of some of the integrated systems currently in use or undergoing evaluation. Note that the list of technologies presented represents a sample of available systems and is not comprehensive.

Predictive Algorithms

Although the efficacy of available integrated monitoring and mitigation systems has received limited scientific evaluation, acoustic, IR and radar-based models for predicting collision rates and implementing curtailment are becoming more sophisticated and continue to undergo assessment (Sections 4.2.3.2 and 4.2.3.3). It has further been recognized that current risk-prediction algorithms (i.e., automated processes designed to predict periods of bat strike-risk and trigger curtailment or other mitigation) are typically based on relatively few parameters such as wind speed, precipitation, and temperature. These risk prediction algorithms might be improved with the identification of additional effective predictors [215]. Improved algorithms may result in more refined modelling and curtailment strategies that will contribute to reduced bat collisions and minimization of energy-production loss because high-risk conditions could be more precisely defined. European studies, for instance, have shown that using a combination of weather data and acoustic bat activity data collected at nacelle height to parameterize mixture models can lead to better, quantifiable risk prediction [191], [216], [217] and also to improved and more cost-effective mitigation strategies. Behr et al. reported preliminary findings from Central Europe indicating that mitigation based on improved algorithms [191] reduced fatality rates by approximately 84% [217]. Initial analyses also demonstrated that for a wind energy facility in Germany, curtailment based on algorithms predicting collision risk from month, time of night, and wind speed (at the nacelle) resulted in minimal production loss (i.e., 0.5 to 1.5% loss of an assumed yearly revenue of 4,500 MWh; [216]).

Wind direction has been identified as a potentially important risk predictor for land-based and/or offshore facilities, and it is becoming clearer that season- or month-specific algorithms could improve predictions [215], [218]. Some current detection-curtailment systems are being informed by multiparametric field studies (e.g., [218]) and it is expected that evaluations and improvements for these and other systems will continue. Condition-specific risk to bats may also be related to prey response, and a better understanding of these interactions may enhance predictive algorithms. For instance, moth and Brazilian free-tailed bat activity at a site in Texas was related to cold front passages (although this relationship varied among seasons; [219]). Research with the goal of improving integrated detection-avoidance systems is a rapidly growing area of interest and will likely offer new and better approaches to bat mitigation in the future.

4.2.3.4 Technology Summary

Ultrasonic acoustic deterrents appear to have the greatest promise as minimization and avoidance tools, and are subsequently receiving substantial support to determine their effectiveness and to optimize mounting options and other design features. Some acoustic deterrent designs are in the advanced field testing phase for effectiveness and are considered near commercial (see Appendix G). Innovative approaches to turbine coatings may offer another effective and economic deterrent tool, and are likely to be most effective when used in concert with acoustic or other deterrent devices. Various detection and monitoring technologies can be effective for identifying risk during operations, particularly when used in tandem, and continue to be explored. Integrated monitoring-avoidance systems and their supporting algorithms represent an area of rapid development and are expected to continue to improve risk predictions and subsequent curtailment strategies. Adoption of these technologies by the wind industry, as they become available, could result in reductions in both bat fatalities and operating costs. It is therefore encouraged that all stakeholders including industry, regulatory agency, and environmental NGOs collaborate to further explore the potential utility and feasibility of these methods, and that current guidelines provide sufficient flexibility to allow promising measures to be included and evaluated through the adaptive management process (see Section 6).

4.2.4 Operational Avoidance and Minimization Summary

Avoidance and minimization strategies for bats need to be tailored to the unique circumstances of a wind energy facility, and this chapter of the Review should be viewed primarily as a menu of potential strategy options for consideration, rather than as a set of recommendations. The general measures listed in Section 4.2.1 are the lowest cost approaches, and can be implemented without impacting power production; however, studies have not been conducted to assess the effectiveness of employing these methods at wind energy facilities. Curtailment is currently the most demonstrably effective approach to reduce impacts to bats and is the most commonly employed avoidance and minimization strategy. Feathering blades below manufacturers' cut-in speeds is often used as a voluntary mitigation measure and altering turbine cut-in speeds has also demonstrated a reduction in bat fatalities of 47-96% [39], [72], [142]–[145], [126]–[129], [134], [139]–[141]. These measures are often employed on a site-specific basis and during periods of high risk to bats, which are based on biological (e.g., migrations, foraging) or environmental (e.g., wind speed, temperature) conditions. There is interest in developing more effective alternatives to curtailment measures, including the use of deterrents. The development of acoustic deterrents and surface coatings on turbine towers to deter bats appear to be most promising. Several bat deterrent prototypes and methods are in development and testing, as discussed in detail in Appendix G; however, these deterrents are not yet practicable for full commercial deployment. Overall, it is recommended that approaches to operational avoidance and minimization maintain adequate flexibility to allow scientific evaluation and improvement of individual strategies, and that the industry, regulatory agencies, researchers and other stakeholders work cooperatively to identify the individual or combined methods that will most effectively minimize impacts to bats while maintaining project sustainability.

5 COMPENSATION AND OFFSETS

When wildlife impacts cannot be avoided, it may be appropriate to compensate for these impacts to reduce or eliminate the net impact to the species in question. This chapter provides an overview of options for compensation and offsets of impact to bats, circumstances in which they may be appropriate, and considerations for their use. Note that the measures provided herein represent conservation actions that have been implemented primarily outside of a wind energy context; they are provided only as examples that might be considered when developing comprehensive strategies for wind facilities, and to guide communication with agencies and other stakeholders regarding broad-scale conservation goals. Likewise, statements regarding the effectiveness of these measures do not indicate that they have been shown to reduce risk to bats at wind energy facilities, but rather have been demonstrated to be effective conservation tools in other contexts.

Bats or their associated habitats can be displaced or altered by human activity, but may be replaced through compensation and offset options. A number of these options have been implemented or considered within various industries including wind, forestry, mining, agriculture, and aggregates. For the wind industry, compensation and offset options may be employed to: 1) mitigate for any residual effects that might be expected after avoidance, and minimization measures have been considered, or 2) mitigate for unexpectedly high individual impacts observed at an operational facility [165].

Compensation and offset options can be supplemental measures or may be taken in lieu of avoidance and minimization options, contingent on project-specific conditions. They also may be considered at all phases of project development and operations. These options include (but are not limited to) habitat protection or enhancement, reducing the impacts of WNS, long-term forest management, captive programs, and conservation banking. Based on publicly-available reports the options provided below, with a few exceptions (e.g., hibernacula gates, habitat protection, conservation banking), have not yet been implemented by wind energy projects in the U.S. or Canada and are provided only to offer potential future opportunities. Note also that although not specifically identified as a limitation, partnerships with landowners or other industries will likely be necessary to implement many of these options and may not always be feasible.

5.1 Habitat Protection or Enhancement

In the case of species for which critical habitat has been identified [44], habitat protection measures can be considered as a form of habitat offset. These measures may include protection of habitat used by bats at any point during their life cycle, including maternity roost habitat, hibernacula, or other habitats (or potential habitats) considered important to the species. Rather than creating new habitat, this approach identifies important habitat and takes steps to protect the habitat from future impacts. Protection could include acquisition and/or donation of land for protection, or working with existing organizations or landowners to provide resources to protect existing habitats (e.g., installing bat gates on existing caves or abandoned mines). Habitat protection, restoration, or enhancement support has been included in Habitat Conservation Plans (HCP) for several wind energy projects in the U.S., with a primary focus on offsetting potential effects on Indiana bat and northern long-eared bat [135], [220], [221].

5.1.1 Artificial Bat Houses

Artificial roosting structures can be used as a compensation tool for bat maternity colony roosting habitats that are displaced by anthropogenic causes, and the installation and support of artificial roost studies have been employed as offset measures at wind energy projects in the U.S. [220]. Artificial roosts (e.g., bat houses) can provide good quality habitat for bats given proper design and placement. Bats have been found to use a variety of different artificial house designs [222]–[224]. In northern Arizona, for example, resin houses appeared to be preferred over wood houses, as were clustered houses over single houses, with these structures showing earlier colonization [224]. Resin houses also typically last longer than wood houses but are more expensive to install. In Pennsylvania, bats used artificial houses that received at least 7 hours of direct sunlight, were attached to the building that formerly housed the colony, had high temperatures (8 to 10 °C above ambient temperatures), and were wide enough ($\geq$ 76 cm) to enable bats to roost side by side [222]. Findings that indicated preferences for these placement and design features appeared to be species-specific, as they were driven by big brown bat and little brown myotis use of the artificial houses.

It is recommended that artificial houses be designed to: 1) mimic natural roosts (i.e., height, micro-climate, design), 2) use known requirements of target species, and 3) exclude non-target species to reduce competition for roosting structures [225]. Many species-specific factors (i.e., morphology, mode of flight, diet, group size, social behaviour) influence house selection requirements [225] and these factors may be taken into account when considering the use of artificial bat houses (Section 2 and Appendix A). Artificial bat house installation represents a form of habitat creation or enhancement that may be considered by the wind industry as a method to mitigate or offset potential effects from individual projects.

5.1.2 Snag Trees

The wind industry may consider the creation of standing dead trees ('snags') in targeted offsite areas, as these features can provide habitat to several bat species that use these trees as roosting sites. There are several ways to create snags including: 1) removing the top third of a tree and half of the remaining side-branches, 2) leaving the top of the tree and removing the majority of side-branches, or 3) girdling (i.e., removal of a strip of bark from around the circumference of a branch or trunk to cause intentional death to the area above) [226]. Snags are known to be important habitats for some bat species, although success of girdling trees to create snags for use by bats is currently unknown.

5.1.3 Artificial Bat Bark

Bats will often roost behind loose bark and within bark slits [226]. Roosting slits for bats (i.e., bat bark) may be added to snag trees that are tall enough and wide enough in diameter to accommodate the cuts. The bat roosting slits should be at least eight inches deep, one or more inches wide, and angled sharply upwards. The slits should ideally be located in an area free of branches to allow bat entry, and slits that are located higher in the tree are more likely to be used due to increased sun exposure [226]. Artificial bat bark is also commercially available for use.

In an effort to provide habitat alternatives to bats, one observational study in northeastern U.S. placed artificial bark on man-made snag trees that were textured on the backside, along with eco-shake shingles (small shelters with cues that would likely support the bats' visual preferences and temperature requirements) [156]. Although no scientific analysis was conducted to evaluate success, observers reported that Indiana bat (the study's target species) moved into the tree with the artificial bat bark and eco-shake shingles by the hundreds, with 451 bats roosting in one such shelter. The bat colony has reportedly since remained at the site for six years. Similar roosts using artificial bark have been established in seven U.S. states, and six bat species have been observed using the artificial roosts including tri-colored bats, little brown myotis, evening bats, big brown bats, Indiana bats, and northern myotis [156]. The artificial bark method has recently been recommended as a compensation and offset option for wind energy facilities [156], but studies evaluating its effectiveness for offsetting bat fatalities have not yet been conducted. Artificial bat bark may be used as a form of compensation and offset for the wind industry to create habitat for bats, and may be considered as a method to compensate for target bat species known to use these types of habitats for roosting (Section 2 and Appendix A).

5.1.4 Bat Gardens

Insectivorous bats require a source of insects to support foraging needs of local populations. Strategic planting of some flowering plants can help attract insects to an area at appropriate times of year and may support foraging insectivorous bats [227]. Plantings for the purpose of promoting foraging bat activity may include flowers that bloom late in the day and are night-scented to attract nocturnal insects, such as moths and beetles [227]. Plantings will ideally consist of locally native and habitat-appropriate plant species.

5.1.5 Abandoned Mines

Several species of cave-roosting bats are known to use abandoned mines as hibernation or maternal roost sites, and protection or management of these habitats may be an option for the wind industry when developing compensation and offset strategies. Approximately 25 bat species in the U.S. are known to roost in abandoned mines, 22 of which (including 10 which also occur in Canada) are considered dependent on abandoned mines for at least part of the year (e.g., hibernation) [228]. The management and protection of abandoned mines, which could be considered as a compensation option for wind energy facilities, involves addressing the challenge of protecting roost habitats for bats while still providing for human safety.

The explicit characteristics that define the quality of a particular abandoned mine for bats are currently unknown [228]. Different species of bats have distinctive habitat requirements and life cycle patterns that influence the conditions under which they use abandoned mines for roosting or hibernation. In a study conducted in the U.S., bats were observed using abandoned mines as roosting habitats at elevations of approximately 1,770 to 3,700 m (average 2,260 m) [228]. Typically bat hibernation sites are cold, ranging from near freezing for big brown bats to warm (12-14 °C) for tri-colored bats [228]. Maternity sites for some bat species (e.g., gray bat [*Myotis grisescens*] and Townsend's big-eared bat) tend to be warmer than hibernation sites (e.g., 14-25 °C for gray bat) [228]. These findings indicate that abandoned mines (or caves) that provide optimal conditions for bats trap cold air for hibernation or warm air for maternity roosting. Effective mine management will typically include identifying target species, type of use (i.e., hibernation, maternity, bachelor, mating), spatial scale (e.g., roosting/hibernation habitat; entire mine, complex of mines, opening(s)), and temporal patterns of use [228].

Habitat restoration of mining operations has been shown to be beneficial to bats. A project in Kansas showed that a strip coal mine pit that was backfilled and restored to protect gray bats successfully attracted bats [228]. This habitat restoration included relocating the strip pit lake and planting a 100-foot (i.e., approximately 30 m) buffer zone of native trees and shrubs around the lake. Objectives were to maximize fish and insect reproduction (i.e., for bat foraging), to help protect foraging bats from predators, and enhance bat feeding opportunities. At the end of the fourth year of reclamation, monitoring indicated gray bats were using the restored habitat area [228]. Various habitat restoration and enhancement measures have also been developed to protect and enhance habitat for Indiana bats at coal mining projects [229]. These measures include avoiding impacts to maternity roosts and known hibernacula, protecting riparian corridors, restricting tree-cutting by season, staging tree removal, avoiding hazardous materials, implementing erosion and sediment controls, and determining post-mining land use. Compensation options for mine development in Ontario include avoiding clearing at mine entrances where possible, and avoiding removing (or fully restoring) protective forest cover leading to hibernacula sites to promote the site's internal temperature, air flow, and humidity characteristics [230]. Forest cover is also expected to facilitate the movement of bats to and from these abandoned mine sites. Finally, gates can be installed at abandoned mines to minimize disturbance from humans and large predators (see Section 5.2.3).

The effectiveness of employing these habitat restoration measures to mitigate potential bat impacts has not been extensively studied, however, and bat monitoring subsequent to restoration activities may facilitate increased understanding of how well these measures perform. The wind industry may be able to partner with efforts to explore the effectiveness of these tools as part of compensation strategies.

5.1.6 Forest Management

Long-term forest management has been shown to improve habitat for bats if harvest strategies are employed that maintain bat habitats [231]. These management strategies may also be species-specific and can be designed to target bat species of interest within a specific area. For wind energy developers that are stakeholders in local forest management, long-term management of surrounding habitats may: 1) help minimize the potential attraction of bats into a project area by providing roosting and foraging habitats far enough away to prevent turbine-related bat fatalities and thereby supplement avoidance and minimization strategies [165], or 2) compensate for potential impacts by enhancing habitat in areas that were previously less suitable for bats or for which support (e.g., funding) for long-term management was not available. A detailed discussion of effective forest management strategies for bats is included in Appendix H.

In general, bats select native forests with high structural complexity for foraging and roosting areas [165]. The maintenance and preservation of existing conditions in mature forests and the acceleration of succession in young forests are viewed as important for bat conservation [165]. These activities may include the preservation of older trees with cavities and well developed branches and the preservation of snags. Some forest types may require branch thinning in order to create flight corridors for bats with less manoeuvrable flight patterns. The preservation of vertical heterogeneity to promote use by a variety of bat species with differing niche requirements is also a management option. Effective forest management practices for bats also vary by region, and may include consideration of life-cycle timing of local bats (and other wildlife) and habitat preferences of target species. For instance, in central Ontario, it is recommended that forest managers implement timber harvest strategies that retain remnant old-growth white pine stands in the landscape, preserve snags, maintain large live trees in selectively logged forests, and promote regeneration of second-growth white pine stands rather than harvesting at younger ages [231].

Long-term forest management practices can improve forested habitats for bats if appropriate, species-targeted strategies are employed. Forest management strategies will ideally align with the habitat needs of target bat species (Section 2 and Appendix A) as well as habitat conditions in the surrounding landscape. Forest management practices, targeting specific bat species, can be implemented as a compensation and offset option to enhance bat habitats outside wind facility areas and as a result potentially prevent turbine-related bat fatalities by promoting avoidance of these areas.

5.2 Reducing Impact of White-nose Syndrome

The greatest known threat to many North American bat populations is WNS. White-nose syndrome is a typically fatal disease caused by a dermatophyte fungus (Pd), believed to have originated in Europe [232]–[236], that causes fuzzy white fungal growth on bat muzzles and ears, elicits skin lesions, disrupts wing circulation (e.g., from scar tissue, holes) and skin respiration, and promotes dehydration [95], [237]. It is well-recognized that WNS presents a much greater risk to bats overall than does wind energy, and that wind energy facilities do not generally affect the species most strongly impacted by WNS. However, knowledge of the disease and its implications for bat populations can help identify conservation opportunities that may be incorporated into compensation and offset strategies as appropriate. At the time of this review, WNS has been identified as present in five Canadian provinces (Table 5-1) and 31 U.S. states; however, it is important to note that spread of the disease has been rapid, with recent records from northwestern U.S. indicating that western provinces may soon be at risk. A full discussion of WNS is provided in Appendix D, including impacts to bat populations and finer-scale distribution of the disease. Summaries of potential compensation and offset options that may be considered to reduce the impact of WNS are presented below.

Table 5-1 Distribution of WNS in Canada [10][a]

Province / Territory	Fungus (Pd) Confirmed in Bats
Alberta	
British Columbia	
Manitoba	
New Brunswick	X
Newfoundland & Labrador	
Northwest Territories	
Nova Scotia	X
Nunavut	
Ontario	X
Prince Edward Island	X
Quebec	X
Saskatchewan	
Yukon Territory	

[a] Distribution of WNS in Canada is current as of January 2018.

5.2.1 Potential Bat Treatment for WNS

Research indicates that infected bats can recover from WNS when held in captivity and provided with supportive care (i.e., warmth, food, and water) for 70 days [238]. These results suggest that the bat immune system is suppressed during hibernation when body temperature is low, which may reduce potential for recovery from WNS during hibernating periods. Skin proteins can also be involved in the immune response of bats to fungal infection [239], and bacteria occurring on the skin of bats may inhibit or suppress fungal growth for at least 35 days [240]. In all cases, the extent of immune suppression was dependent on the initial concentration of Pd and bacteria.

Studies have also been conducted to identify viruses that infect Pd and to determine how these may affect the fungus [241], [242]. This information will inform efforts to develop Pd management strategies that may reduce the virulence of the fungus to bats. An oral delivery mechanism to distribute vaccines among colonial roosting bats has been developed and related studies are currently in progress to identify possible vaccines for WNS [243]. The goal of these studies is to use laboratory infection trials with first year survivors to investigate acquired resistance to Pd infection and its potential relationship to survivorship in the second year of infection. The results of ongoing research into immune suppression and resistance factors may allow for greater opportunity for the wind industry to support large-scale efforts to eradicate, or significantly minimize, the presence of WNS as a compensation option for affected species.

5.2.2 Biological and Chemical Controls for WNS

Biological and chemical control options have been tested for their potential to reduce WNS. Bacterially-produced volatile organic compounds (VOCs) and multiply induced *Rhodococcus rhodochrous* (Rr) may be used to inoculate bat hibernacula in combination with maintaining suitable temperatures (either naturally or artificially) to reduce the impacts of WNS on bat populations. Supporting the inoculation of hibernacula may be an offset option for wind energy facilities.

Several studies also have examined whether antifungal drugs and biocides are effective against Pd [244], [245], with a number of azole antifungals, a fungicide, and several biocides demonstrating inhibition of the growth of Pd. Recent research indicates that the Pd pathogen is also sensitive to the DNA alkylating agent methyl methanesulfonate (MMS) [246]. These biological and chemical controls might provide a viable means to rehabilitate affected bats and/or for decontamination of Pd at known hibernacula (i.e., caves, abandoned mines) and may be considered as a potential compensation tool for the wind industry.

5.2.3 Protection of Abandoned Mines to Reduce Spread of WNS

Gates are an option to consider in the management of abandoned mines and have been included as a compensation and offset tool for wind energy projects in the U.S. that present potential risk to Indiana bat and northern long-eared bat [135], [220]. Gates can be installed to reduce human foot traffic, which has been identified as a primary factor in the spread of WNS [230], or to exclude large predators. In Colorado, a statewide conservation effort has documented 11 species of bats roosting in abandoned mines and has installed gates at 142 mines [247]; all of the bat species documented using the abandoned mines before the gates were installed continued to use the abandoned mines after installation. Proper design and installation of these gates is critical. Poorly designed gates can significantly alter air flow, act as physical barriers to bats or other species, and can be easily bypassed by humans and/or predators. Conversely, good gates control human access, are vandal resistant, and provide unrestricted air flow and bat movements. An angle-iron gate is recommended for protecting colonies of bats in abandoned mines, due to its strength, minimal air flow, and maximum bat movement space. This design is recommended by the USFWS for use at caves or abandoned mines that support bats [228]. In Ontario, provincial recommendations suggest that human access to caves and abandoned mines be prevented (i.e., gates, fences, bars, metal grids, signage, trails/roads blocked) [230]. Caves of known bat hibernacula in Alberta have also been closed to human access using signage [248]. The installation of gates is one of the few compensatory options that has been employed at several wind energy projects, is widely considered to be effective by regulatory agencies in the U.S., and may be included in compensation plans in Canada.

5.2.4 Hibernacula Decontamination and Enhancement

The Ontario MNRF has created Ontario's WNS Response Plan in collaboration with the Canadian Wildlife Health Cooperative (CWHC) and the Ontario Ministry of Northern Development and Mines, which identifies the risks to individual bats in the province and allows for coordination across agencies relating to prevention, surveillance, and research [249]. The plan outlines WNS prevention, monitoring, and research priorities including those for hibernacula decontamination and enhancement. Although effective measures have not yet been clearly identified, it is expected that research in this area will continue to be a priority and may offer future compensation and offset options to the wind industry. Studies have explored the possibility of influencing the fungal characteristics of soils to reduce the potential for cave soils to serve as reservoirs for Pd [250]–[252]. One study used a culture-based technique to investigate the diversity of fungi in soil samples from 24 bat hibernacula in the eastern U.S. [250]. Pd was isolated from the soils in three hibernacula where WNS is known to occur. This could help characterize the diversity of fungi in hibernacula to improve the understanding of the ecology of Pd and potentially identify differences between this fungus and other non-pathogenic relatives. This information could provide for new potential compensation and offset measures for the wind industry, by supporting research or activities for altering bat hibernacula soils to reduce WNS in these habitats.

There is evidence that artificial warming of areas within hibernacula could increase the survival of WNS-affected bats [253]. Increasing temperatures to 28 °C in hibernacula can improve bat survival up to 75%. Recent research has also determined that the Pd pathogen is extremely sensitive to UV light which could be potentially be used in cave treatments to reduce the presence of the disease [246]. As a compensation and offset option, the wind industry could consider funding further research into artificial warming or UV cave treatments as potential management tools for increasing bat survival.

5.2.5 Research and Outreach to Reduce Spread of WNS

The CWHC has established A National Plan to Manage White-nose Syndrome in Bats in Canada [254]. This plan builds on a previous national management plan [255] and outlines specific goals and action items, including developing best practices for the protection of bats in various industries and monitoring WNS treatment testing results. The plan states that research funding for identification of undocumented hibernacula will be helpful if and when effective control measures are developed to control the disease of WNS. The CWHC has also established a Western Canada White-nose Syndrome Transmission Prevention communication pamphlet, created by the Western Bat Working Group to increase awareness among recreational cavers and other users of potential bat hibernacula of the threats posed to bats from transmission of WNS from infected to uninfected sites [256]. It is possible that future compensation measures available to the wind industry may include providing funding to support research and outreach efforts that will help advance the objectives of the national WNS management plan. In the U.S., support of bat research programs in general has been included as a compensation and offset tool for wind energy projects focused on minimizing affects to Indiana bat [221], and there is potential for similar options to be adopted, as appropriate, for wind energy projects in Canada.

5.2.6 Captive Bat Programs

Captive rearing programs can be used to increase or stabilize bat populations by breeding bats in captivity for release into the wild. Captive programs can also be used to temporarily keep bats under controlled conditions during high risk periods such as hibernation, when WNS fungal infection is most likely. Bat captive programs have the potential to positively impact bat populations by increasing bat numbers and overall population viability.

If a wind energy facility is found to have had negative effects on individual bats, a potential offset option for these impacts may be to support captive breeding programs to increase bat numbers and overall population viability in an area. A full discussion of the effectiveness and status of captive rearing programs is provided in Appendix H. In general, silver-haired bat, eastern red bat, and hoary bat make up the majority of bat fatalities at wind energy facilities and have also been shown to have moderate breeding success in captive programs. As such, it is recommended that captive breeding programs supported by a wind energy facility preferentially target bat species of concern in the facility area as determined by pre-construction monitoring or observed fatalities (e.g., species-specific) during operations. However, there have been minimal bat captive breeding programs completed to indicate the success/failure of these programs, and this tool has not yet been implemented as a way to offset potential bat affects at wind energy facilities. In addition, certain target species may not be recommended for these programs. Providing funding to support research on the success/failure of captive breeding programs may also be an offset option for individual projects. While this type of research endeavour provides a promising opportunity for increasing local bat population numbers, it would require cooperation and approval among industry and regulatory agencies to be considered a viable compensation option.

5.3 Conservation Banking

Conservation banks are permanently protected lands that are managed for species that are endangered, threatened, or that are otherwise considered a species-at-risk (e.g., candidate for listing) [257]. Conservation banks function to offset adverse impacts to these species and their habitats that have occurred elsewhere. Banking measures are typically designed to conserve threatened and endangered bat species and habitats via a credit purchase system, in which credits are purchased through established or new habitat banks to offset potential impacts to those species at a wind facility or other development. The goal of this system is to provide bat habitat compensation through large contiguous habitat areas, as opposed to individual (smaller) habitat areas in closer proximity to individual projects.

The conservation banking system can be privately or publicly owned. In the U.S., the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration-National Marine Fisheries Service, and California Department of Fish and Wildlife participate in conservation banking [258]. Conservation banking has been included in bat HCPs in the U.S. [135], and has the potential to be used as an effective mitigation tool for wind energy facilities in Canada, pending the identification of appropriate conservation partners.

5.4 Compensation and Offsets Summary

There are a number of compensation and offset options that may be considered by the wind industry. These options can be implemented to offset potential impacts to bats and/or their associated habitats from the development of a wind energy facility. Each option provides distinct benefits to bats, but is also subject to limitations that can affect effectiveness or applicability. Common compensation and offset options can be categorized as habitat protection or enhancement, reduction of WNS impacts, and conservation banking. Some options, such as habitat protection or enhancement are widely applicable and feasible, whereas others like reduction of WNS impacts are more limited in scope or practicability. Measures involving forestry practices will likely require coordination with foresters and landowners, which could be facilitated by regulatory agencies through incentives programs or other initiatives. Intensive methods such as reduction of WNS impacts would also require regulatory agency engagement and collaboration with academics or wildlife conservation organizations.

The compensation and offset options discussed in this chapter are summarized in Table 5-2. Prior to committing to a compensation or offset option, wind energy facility owners can carefully evaluate the practicability and likelihood of success of their proposed approach, and regulatory agencies may work with the industry to identify and facilitate practicable and effective solutions.

Table 5-2 Compensation and Offset Options Summary[a]

Options		Benefits	Limitations
Habitat Protection or Enhancement	Artificial bat houses	• Provide good quality habitat for bats with proper design and placements • Commercially available	• Design and placement may be species-specific and difficult to target species in areas with multiple target species • Success may be species-dependent • May not see immediate success as occupation may take place in subsequent years • Partnership with landowner required
	Snag trees	• Provide good quality habitat for bats, by creating conditions already found in nature	• Long-term success of girdling trees to create snag trees for use by bats is unknown • Applicable only for tree roosting species • Does not provide immediate habitat and may take several years for suitable characteristics to develop • Partnership with landowner required
	Artificial bat bark	• Provide good quality habitat for bats with proper design and placements • Commercially available	• Design and placement may be species-specific and difficult to target species in areas with multiple target species • Applicable only for bats that roost behind loose bark • Partnership with landowner required
	Bat gardens	• Provide good quality foraging habitat for bats with use of proper plant species	• Partnership with landowner required
	Abandoned mines	• Protects existing habitat for bats by maintaining internal and external conditions and limiting human disturbance	• Applicable only for cave-roosting bats • Partnership with landowner required

Table 5-2 Compensation and Offset Options Summary[a]

Options		Benefits	Limitations
Habitat Protection or Enhancement	Long-term forest management	• Can include logging practices, management of tree species composition and canopy height in forests, and agricultural practice within nearby forested habitats • Promotes good quality habitat for bats and may minimize potential attraction of bats to wind facility areas	• Will ideally consider a variety of factors, including existing species diversity, climate, soils, hydrology, and alignment with target species habitat which can make it difficult to target multiple species • Partnership with forestry companies and/or landowners required • Must adhere to appropriate seasonal restrictions such that activities do not interfere with actively roosting bats
Reduction of Impacts of White-nose Syndrome (WNS)	Potential bat treatment for WNS	• Reduces impacts of WNS on infected individuals	• Application at population-level is difficult • Treatment options are in preliminary stages of development and not available for widespread use
	Biological and chemical controls for WNS	• Reduces impacts of WNS via bat and hibernacula treatment • Recent research indicates high Pd sensitivity to MMS	• Application at population-level is difficult • Treatment options are in preliminary stages of development and not available for widespread use
	Protection of abandoned mines	• Provides control for spread of WNS by controlling access to abandoned mines with suitable habitat	• Applicable only for cave-roosting bats • Partnership with landowner required
	Hibernacula decontamination and enhancement	• Provides bat hibernacula treatment for WNS • Protects existing habitat for bats by maintaining internal and external conditions • Recent research indicates high Pd sensitivity to UV light	• Applicable only for cave-roosting bats
	Research and outreach to reduce spread	• Provides funding to support research and outreach efforts • Will help reduce scientific uncertainty over time and improve bat conservation efforts at the population scale	• Will require establishing partnerships with conservation and research institutions • Availability of the option within Canada is unknown at present

Table 5-2 Compensation and Offset Options Summary[a]

Options		Benefits	Limitations
Reduction of Impacts of White-nose Syndrome (WNS)	Captive bat programs	• Captive programs can be used to supplement local bat populations or allow re-introductions into areas where populations have been diminished by WNS • Captive programs have demonstrated success for some bat species	• Bats have complex requirements that are challenging to sustain in captivity • Captive programs have limitations for some bat species including low initial population numbers or low survivorship in captivity • Animal Care & Use standards and/or provincial regulations may be limiting or prohibitive • Due to limitations, this approach is currently not anticipated to provide population-level support
Conservation Banking	Contributions to established conservation banks	• Conservation banks are administered by a third party, thereby relieving developers of ongoing administration responsibilities • Can be targeted to specific species of concern and result in net benefit to the species	• Availability of the option within Canada is unknown at present and reliant upon identification of conservation partners

[a] For more detail on forest management strategies and captive rearing programs for bats see Compensation and Offset Options in Appendix H.

6 ADAPTIVE MANAGEMENT FRAMEWORK

Adaptive management refers to a structured, iterative process by which recurrent decisions are made based on information gained from the results of prior management actions [259]. An adaptive management approach is considered most appropriate when there is scientific uncertainty about the predicted outcomes of the actions tied to a decision [259]. Typically, initial decisions are driven by the best available science and by stakeholder values and objectives, with the acknowledgement that there are uncertainties associated with the predicted outcomes of these actions [260]. Outcomes from each round of decisions are used to inform the next set of management actions with the goal that uncertainty is reduced with each round and managers are better able to predict and obtain desired results.

In a wind-industry context, adaptive management can be implemented at the individual project level, and at broader regional, national, or international scales. At the project level, adaptive management provides a logical approach to assess the effectiveness of specific measures and inform ongoing management decisions at that facility, while balancing cost and energy production considerations. Wind projects are often constrained by power purchase agreements and other factors that may limit the feasibility of multiple iterations of decision making at a single project. However, by incorporating information and methodologies from many projects at a broader scale, the financial sustainability for individual projects is preserved, while providing valuable data to inform policy, reduce uncertainty about wildlife populations potentially at risk, and help guide decisions at new projects [261]. As has been noted by the International Energy Agency (IEA), learning outcomes from such a broad-scale approach could have greater overall benefits in terms of protecting wildlife, improving future decision making, and supporting the further development of the industry [261].

This chapter offers an adaptive management framework that is objective driven, provides a high-level overview of available management options, and incorporates monitoring at key decision points in order to improve decision-making over time. It is important to note that monitoring in an adaptive management framework is narrowly-defined and designed to improve specific decisions. At the individual wind project-level in particular, monitoring strategies will typically be hypothesis-driven and aimed at informing specific management decisions [261]. The framework is not intended as a prescriptive method for dictating specific decisions or policies. Rather, it is provided as an informational resource to guide decision making processes that result in more predictable outcomes, thereby ensuring that wind energy production and its role in reducing climate change impacts moves forward via a sustainable, adaptive process. Sections 6.1 and 6.2 define the framework context, including overall objectives and the process by which industry decisions can influence objectives related to bat conservation. Section 6.3 presents a decision tree that can be used to inform decisions at various project phases (e.g., siting, operations, fatality monitoring).

6.1 Mitigation Hierarchy

Mitigation is defined as any process or action designed to avoid, reduce, or compensate for the potential impacts of a project [165], [262], [263]. In the context of the framework presented here, impacts refer to the potential effects on bat habitats or fatality rates that may result from wind energy development, with the understanding that habitat and mortality rates are strongly influenced by other external factors (e.g., climate change, contaminants, intentional killing [8], [9]). A common approach to assessing the suite of mitigation options available to the wind industry is to view them as a hierarchy, with preferred practicable options considered first, second-level options considered if potential impacts remain after first-level approaches have been addressed (i.e., implemented or modelled), and third-level options only considered if predicted or observed impacts remain after first- and second-level options have been employed [165], [262]. It should be noted that mitigation hierarchies alone, which are focused on implementing mitigation and monitoring measures to reduce effects on wildlife at individual projects, are not integral to the broader adaptive management goal of reducing scientific uncertainty and facilitating learning about bat and wind energy interactions [261]. However, as has been demonstrated at several projects in Europe [261], an adaptive management 'learning by doing' approach can be effectively integrated into mitigation hierarchy strategies if implementation and monitoring plans are designed appropriately (i.e., to address broader, pre-defined questions).

A conceptual mitigation hierarchy for wind industry developers concerned with potential bat impacts is presented in Figure 6-1.

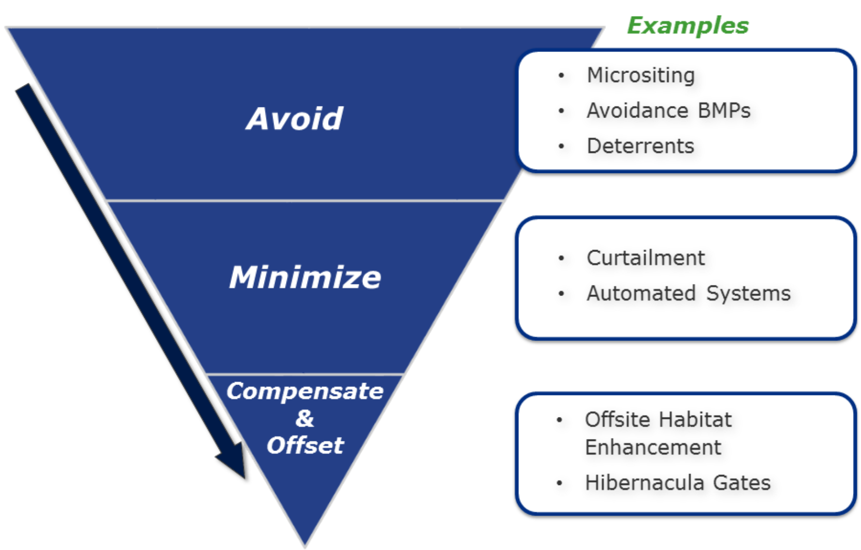


Figure 6-1. Mitigation hierarchy for addressing potential impacts to bats. Preferred options would be to first avoid, then minimize, then compensate and offset if necessary (Modified from [165], [261]**; areas depicted for each set of options represent expected level of prioritization).**

According to this hierarchy, project developers and regulatory agencies can prioritize options to first avoid, then minimize impacts that cannot be avoided, then compensate and offset any remaining potential residual impacts that would be considered ecologically significant. Note that these options may be considered within each stage of wind energy facility development; for instance, pre-construction avoidance, minimization and compensation options may be considered prior to consideration of operational avoidance and minimization measures. First-priority avoidance measures are primarily designed to be implemented in the siting phase, can be very effective for reducing potential bat impacts, and are often cost-effective. These typically include industry BMP for design and construction activities along with other siting considerations (see Section 4). If potential impacts remain after informed siting decisions have been made, options for avoiding and minimizing bat fatalities during operations may be considered, including the use of operational BMP, deterrents or targeted curtailment. In this context, avoidance often refers to avoiding interactions between bats and turbines, which likely minimizes fatalities, but is not likely to completely preclude them. Any significant ecological impacts that cannot be avoided or minimized may be addressed through habitat offsets, contributions to conservation mitigation banks, or contributions to efforts to reduce the impacts of other stressors on bat populations (e.g., spread of WNS; see Section 5).

This tiered, hierarchical approach to exploring mitigation options is widely accepted in Europe [165] and reflected in the stepwise, sequential structure of U.S. and Canadian guidelines (Ontario's *Bats and Bat Habitat: Guidelines for Wind Power Projects*, Alberta's *Bat Mitigation Framework for Wind Power Development*, *Best Management Practices Guidebook for Bats in British Columbia*, and the *U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines*; [88], [125], [132], [264]). The options available to the wind industry at each stage of the hierarchical decision process can be facilitated using a decision tree approach (Section 6.3). It is important to note that mitigation hierarchies may lead to an overcautious, prescribed approach that is not necessarily aimed at improving scientific understanding or reaching regional conservation goals [261]; the identification of clearly-defined objectives is thus a critical component to the adaptive management process.

6.2 Objectives

Wind energy is a renewable energy source that displaces existing fossil fuel usage and its negative impacts on air and water quality, human health, and wildlife [265]. Because of the net positive value it provides, continued growth of the wind industry will be vital in addressing climate-related impacts on wildlife, including bats. Growth of the industry is determined by the development of economically viable projects, and for individual projects to be viable they must provide predictable levels of energy production. Given the potential for utility-scale wind production to impact bats [3], [9], wind industry developers are cognizant of the need to balance project economics while minimizing the risk that projects will impact bats [259], [266]. It is often possible to identify alternative approaches to development and mitigation planning that achieve the multiple objectives of sustainable project economics and minimizing the potential impacts to bats at the project level. By adopting an adaptive management approach, the wind industry and other stakeholders can also address the shared objective of reducing scientific uncertainties around issues related to bats and wind energy, thus continuing to improve the effectiveness of planning and measures over time [261]. As noted by the IEA, a balanced approach to adaptive management will result in minimizing undue financial pressure on projects while ensuring that the natural resources of Canada and its provinces are protected [261].

There are several means by which the industry can help regulatory agencies and conservation groups achieve bat conservation goals, while ensuring that management decisions do not result in unsustainable project costs. The industry can take measures to avoid or minimize turbine collisions, improve or maintain suitable bat habitat, and reduce WNS mortality as means of contributing to conservation efforts. These objectives can best be attained by using a flexible approach that can include a range of siting, management, and compensatory options at the project planning or operational stages (Figure 6-2). Adopting an adaptive management approach will also help the industry and other stakeholders address the shared goal of reducing scientific uncertainty, so that future efforts aimed at bat conservation will continue to be more effective. To support such an approach the industry, in partnership with agencies, has developed the wind energy bird & bat monitoring database[2] that represents the most comprehensive standardized repository of wind-wildlife data in Canada.

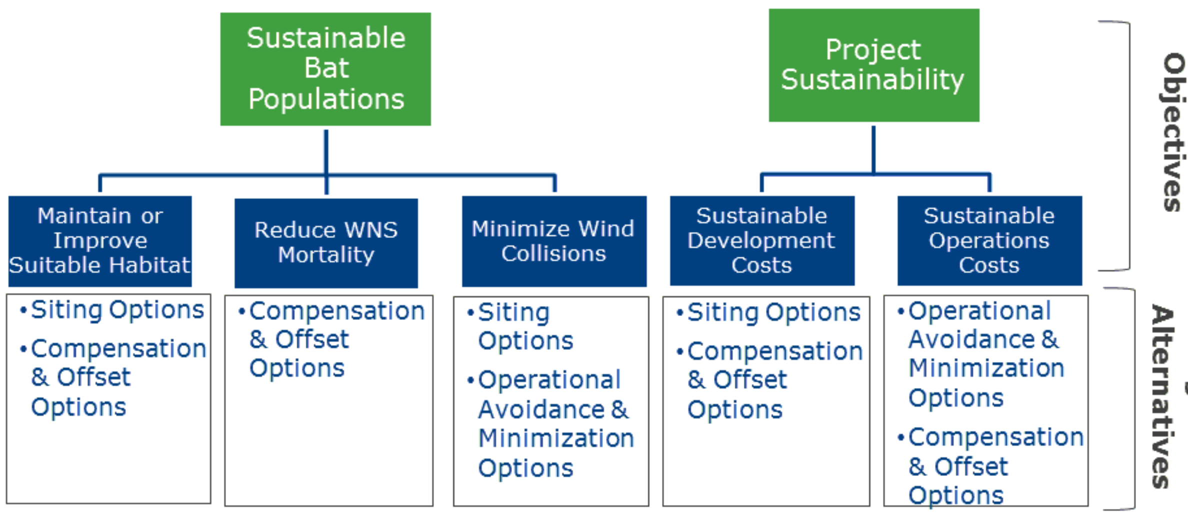


Figure 6-2. Objectives hierarchy for individual wind energy projects, based on the fundamental objectives of maintaining sustainable bat populations and sustainable project costs (including monitoring costs).[3]

A conceptual model of the process by which project decisions can influence bat population sustainability is depicted in the influence diagram in Figure 6-3. Project decisions may be impacted by regional constraints including regulatory agency input and agency guidelines (dashed lines, Figure 6-3). Decisions may be further constrained by environmental and social factors that are beyond the scope of this Review, including external impacts to natural features and sensitive habitat, land-use changes, sound constraints, shadow flicker, landowner preferences, cultural resources, and other stakeholder considerations (e.g., First Nations, local communities, recreational users).

Careful decision-making at the planning and siting phases can minimize habitat loss and can avoid siting in areas with potentially high concentrations of bats (e.g., areas with hibernacula, maternity roosts, high concentrations of wetlands, etc.) where these areas are identifiable and avoidable.

[2] https://www.bsc-eoc.org/birdmon/wind/main.jsp

[3] Only wind energy-related factors that may affect bat population sustainability are depicted; however, this does not imply that many other factors that are beyond the control of the wind industry also influence bat population sustainability (see Section 1; Introduction).

Management decisions made during the operational phase primarily affect collision-related fatalities. Compensation and offset options typically are aimed at protecting or improving the quality of available bat habitat or reducing fatalities associated with WNS. Ultimately, by increasing or maintaining suitable bat habitat and avoiding or minimizing collision fatality risk, the industry can continue to grow without causing negative consequences for bat conservation while adding valuable data to inform future conservation efforts. Decisions at all phases are dependent on site conditions, including species present.

With the recognition that wind energy projects do not tend to affect those species most strongly impacted by WNS, the disease may also be considered when choosing compensation and offset options (see Section 5). Siting, avoidance and minimization, and compensation and offset options available to the wind industry are discussed in Section 6.3.

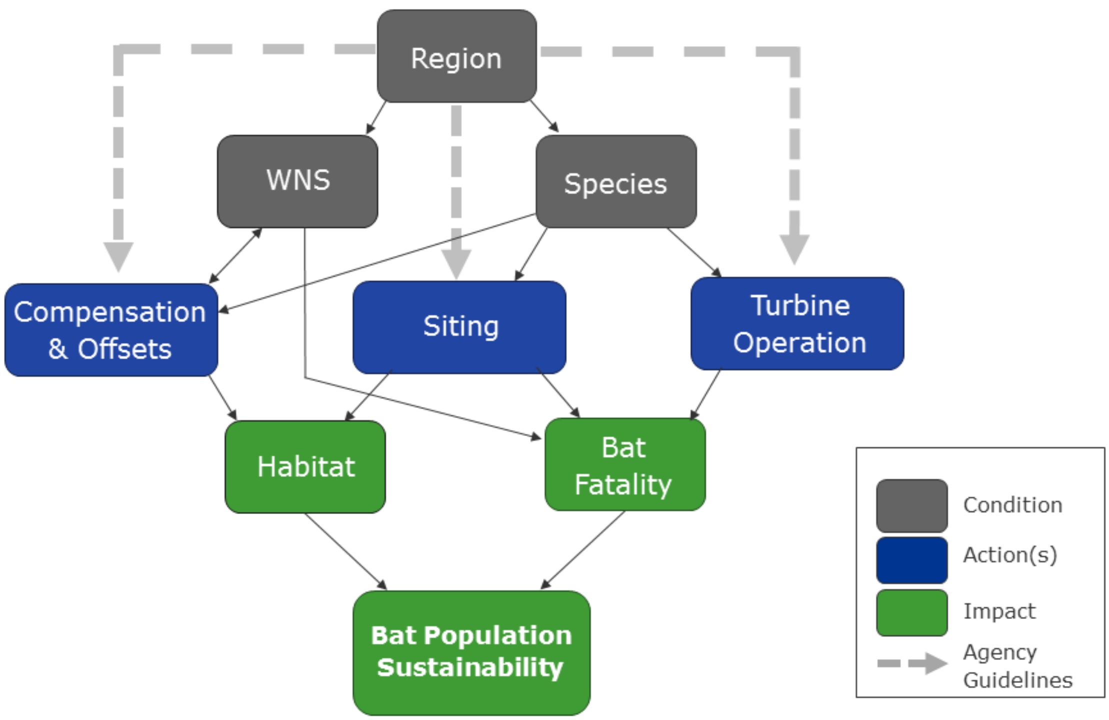


Figure 6-3. Influence diagram depicting key conditions, wind energy management actions, and impacts that may affect bat population sustainability[4].

[4] NOTE: Other influences that impact bat populations such as environmental conditions (including climate change) and other anthropogenic and natural factors are not depicted in the figure but may be considered on a project-specific basis, if information is available.

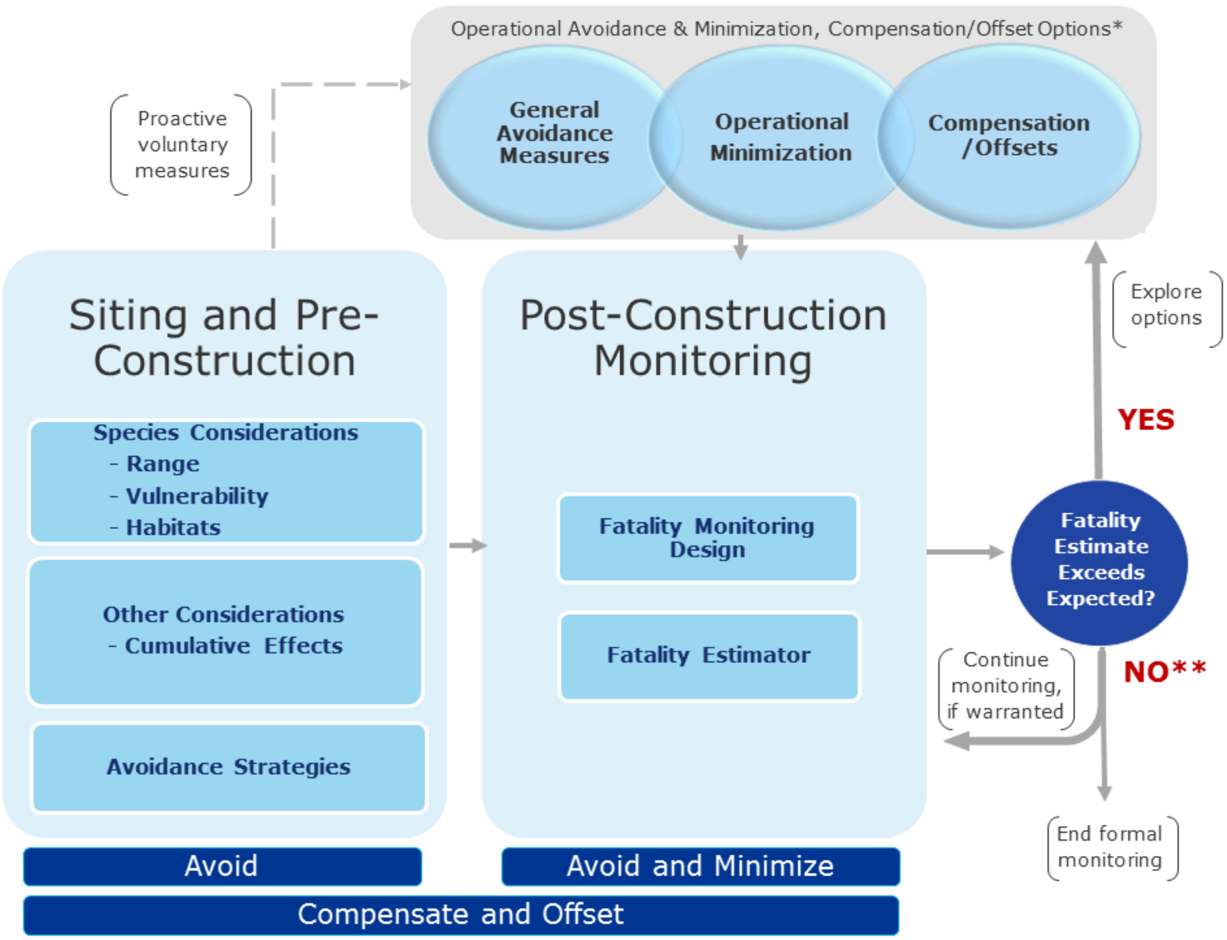
6.3 Decision Tree

Among the common tools used to inform adaptive management decisions are structured and directional decision trees [267]. Decision trees typically include an explicit sequence of discrete decision nodes (e.g., “choose management option a or b”) and conditional nodes (e.g., “known hibernacula or listed species present or absent”) to help guide decision-makers through the decision process [267]. Explicit decision trees can be somewhat prescriptive, however, in that the discrete nodes are often constrained by pre-defined triggers, or thresholds, for example, an annual bat fatality rate [268]–[270]. It is not the intention of this Review to define such thresholds or to provide step-by-step instructions, with the acknowledgement that in many cases thresholds have been identified by individual provinces and will drive the response process. Instead, this section offers a generalized decision-tree framework that incorporates summaries of the types of options available to decision-makers at each stage of the decision process, along with links to details presented in corresponding chapters of this Review. Users may wish to consult the links provided throughout this document (Sections 6.3.1 through 6.3.4) based on project-specific needs and stage of development.

It is the goal of the decision tree presented herein to allow for flexibility in both the decision nodes (i.e., when should action be taken?) and in the nature of the decision response (i.e., what actions should be taken?) for individual wind energy projects. Although many management directives including current provincial guidelines for wind energy (Appendix I) provide fixed thresholds for adaptive management or mitigation, it is important to note that the environmental context of each project is unique, and flexibility is necessary to ensure that thresholds result in sound conservation within that context. Universal thresholds lack the flexibility needed to tailor monitoring and mitigation to population- and site-specific factors. Furthermore, as has been noted throughout this chapter, a key objective of adaptive management is to answer questions and support bat conservation on a broader scale to improve wind energy planning and operations over time [261]. Pre-defined thresholds typically operate on precautionary assumptions that may have very limited value for decision makers to apply lessons learned to future projects [261]. Instead of fixed thresholds for mitigation measures, project-specific triggers are best-designed to reach well-defined provincial goals (i.e., conservation and learning goals), and decisions about thresholds are best made on a project-by-project basis to reach these overarching goals.

Overall provincial goals can be attained by managing for each project using a plan specific to that project. The project-specific thresholds would indicate when an event or pattern at a project is significant enough to trigger additional investigation in an effort to research the cause and potential management responses to facilitate reaching the provincial goal. Similarly, when it is determined that a response is appropriate based on broad-scale bat conservation goals, decisions about specific measures to be employed are most effective when made on a project-by-project basis. As indicated in in Section 4, the practicability of avoidance measures is highly variable among wind energy facilities, and the use of fixed, province-wide thresholds and responses is therefore problematic in terms of conservation impact.

A conceptual depiction of the generalized framework discussed in this chapter is presented in Figure 6-4. The arrows between stages represent next-phase considerations for those who wish to take an adaptive management approach.



* Methods can be used alone or in combination.

** Assess post-construction monitoring program and continue, adjust methodology or end based on previously agreed conditions and regional goals.

Figure 6-4. Conceptual decision tree for new and operational wind energy facilities.[5] Arrows are directional and indicate sequential patterns that could be expected in the decision process.

The framework presented here includes one decision node based on project-defined expectations of bat fatalities. In any decision analysis, it is imperative that decisions at each node be data-driven and based on monitoring results to determine the status of 'state' variables (in this case, fatality rates) compared to expectations and goals. Monitoring plans are most effective when targeted towards answering specific questions and reaching conservation goals at the regional scale, and when data from multiple projects are considered. Thoughtful, targeted monitoring that is replicated across

[5] Associated tables and figures summarizing options available within each phase of decision-making are provided in Sections 6.3.1 to 6.3.4.

projects will increase the power of inferences without increasing the monitoring burden on individual projects [261].

In the decision tree presented in Figure 6-4, expected bat fatalities are contingent upon earlier stages of the decision process, including pre-construction assessment and choice of fatality estimator. The term 'expected' in this context does not indicate that if observed estimates exceed predicted estimates by any margin specific action is appropriate; instead, action is typically considered when fatalities greatly exceed predicted rates or if regulatory thresholds are exceeded. For instance, operators may be encouraged to confer with agencies and/or other stakeholders to explore further operational avoidance, minimization, and compensatory options, or to participate in local or regional studies to reduce uncertainty about the effectiveness of these measures. If observed fatalities do not exceed expectations, operators may reassess and adjust or terminate (i.e., end formal monitoring) a project's bat monitoring strategy. Readjustment or termination of monitoring is often in compliance with regulatory requirements, but may also be based on the fact that adequate data have been obtained within or across projects to adequately answer targeted questions. It is furthermore expected that as data from the industry are collectively used to address regional questions, therefore reducing scientific uncertainty, the need to take an intensive adaptive management approach at all individual projects will be reduced [261]. It is therefore prudent for each project to jointly assess its monitoring strategy in terms of observed vs. expected outcomes, regional-scale results, and scientific needs to determine if termination or adjustments are appropriate.

There are a variety of methods by which fatalities are predicted, depending on the scope and context of the prediction. For example, observed fatality rates at similar facilities in the same region and habitat matrix are often used to predict overall bat fatality rates; whereas species composition models based on pre-construction surveys are often used to predict species- or guild-specific fatality rates. A full discussion of prediction methods is beyond the scope of this Review but various resources are available to inform project-specific decisions about expected outcomes [271], [272].

6.3.1 Siting and Pre-construction Options and Considerations

Avoidance measures may be considered during siting and pre-construction based on project-specific conditions such as species potentially present, habitat and topographic features, and the likelihood of cumulative effects. Making adjustments such as avoiding habitat removal and limiting turbine placement in areas with potentially high concentrations of bats (e.g., areas with hibernacula, maternity roosts, high concentrations of wetlands, etc.) during the siting and development phase will typically be more cost-effective than measures to minimize risk at turbines during operations (e.g., curtailment).

Developers may consider what species, particularly those that are considered species of conservation concern or those that are more likely to be impacted by wind turbines (e.g., target species), are likely to occur at a proposed project site. Various emerging monitoring technologies may be considered for augmenting or improving understanding of bat activity at a site. Construction activities and turbine placement can be informed by knowledge of habitats that are associated with potential target species [273]. In addition, individual projects can have effects on bats that may add to potential cumulative impacts with other operational and approved wind energy facilities [274]. The likelihood of contributing to cumulative impacts is generally higher in regions with more wind development (for detailed maps of operational wind energy facilities in Canada, see Appendix J). Developers can draw upon publicly available information regarding regional wind development to gain a better understanding of the potential for cumulative impacts from operational and approved projects[6], which can also influence project planning strategies.

After pre-construction and siting avoidance measures have been considered, developers may attempt to predict the potential risk of a project to bats, however, no quantitative models have yet been developed that are demonstrably effective for predicting bat collision risk [17]. If a project will potentially impact bats based on the pre-construction assessment, developers may choose to explore, as proactive measures (either voluntary or through negotiations with regulatory agencies), the various avoidance and minimization options available for use during operations (Section 4). It is also at this phase of the framework during which fatality monitoring and estimation options would be considered (Section 3).

6.3.1.1 Species Considerations

The potential for bat species to occur at a site is contingent upon their respective ranges or distributions, defined as the geographical area within which a species can be found, in combination with habitat preferences (Section 2). It is generally prudent for individual projects to focus on species that are most likely to be at risk based on project location, historical collision data and habitat features within a proposed area. In areas where WNS is present, it may be appropriate to give consideration to species that are known to be susceptible to the disease during the decision process (Appendix D). To determine focal species, the national and provincial conservation status of bat species found in Canada may be considered (Section 2.1), along with the likelihood of impacts from wind, based on observed fatality rates and species population vulnerability (Section 4.1), and specific habitat features associated with each species (Section 2.1). For example, the Canadian ranges of the three SARA-listed species (little brown myotis, tri-colored bat, northern myotis), the three species with the highest fatality rates at wind energy facilities (eastern red bat, hoary bat, silver-haired bat), and one species that may be at risk due to behaviour although it only represents approximately 12% of fatalities across Canada (big brown bat [4], [275]) can be consulted to determine range overlap with a project (Appendix A).

Several methods for pre-construction bat monitoring to determine species presence are also recommended in current provincial guidelines (Appendix I); however, little scientific evidence is available demonstrating the effectiveness of most of these methods for predicting risk to bats (e.g., mist-netting, telemetry) and they are not discussed further in this document. Acoustic monitoring, although generally effective for identifying bat presence and activity levels at proposed wind energy sites, has not been shown to be a good predictor of risk to bats at the project-level. Emerging monitoring options that improve upon acoustic methods, have not yet been independently evaluated, and/or are not yet commercially available may also be considered (Section 4.2.3.1). These emerging options offer opportunity for industry to work with agencies and other stakeholders to study and improve the effectiveness of individual methods, and to incorporate them into comprehensive conservation strategies; such flexibility to consider a range of options is critical to an adaptive management process.

[6] Current installed capacity and information on wind energy in Canada can be accessed at https://canwea.ca/wind-energy/installed-capacity/.

6.3.1.2 Cumulative Impacts

Developers and regulatory agencies are often interested in the potential for a project to contribute to cumulative impacts to bats, although such impacts are extremely difficult to estimate. In the context of wind energy and bat conservation, cumulative impacts refer to the overall effect on bats that may result from “the incremental impact of a project when added to other past, present, and reasonably foreseeable future actions” (e.g., other stressors in the area) [125]. The likelihood of contributing to potential cumulative impacts is generally considered higher in regions with more wind development [274]. Current operating wind energy projects in Canada (current to 8 January 2018) are provided in Appendix J; CanWEA also maintains a regularly-updated information portal that can be consulted to review wind energy capacity (https://canwea.ca/wind-energy/installed-capacity/). Cumulative effects analyses are recommended or required by agencies under some conditions in some provinces (e.g., ON REA process and AB’s *Wildlife Directive for Alberta Wind Energy Projects* [276]; Appendix I). Analysis of cumulative effects often requires assessment of potential impacts in the vicinity that may impact target species, including wind energy projects, mining operations, or other developmental activities.

6.3.1.3 Avoidance Strategies

Individual bat species have varied habitat needs and will thus be affected differently by habitat removal or alteration activities and turbine placement decisions. Where practicable, developers should consider avoiding or minimizing removal of habitats that species are likely to use during one or more critical stages of their life-cycles (e.g., maternity roosting, hibernation, juvenile dispersion). Turbine placement decisions may consider the potential for increased collision rates in areas where bats are known to concentrate. Some provincial guidelines recommend specific setback distances for turbine placement, however, prescribed setback distances reduce flexibility in responding to bat concentrating features, and customizing setbacks to project circumstances is likely to provide greater conservation benefits (Appendix I). Species-specific habitat associations are summarized in Section 2.2. Projects may also consider the potential effects of landscape modification during the siting phase and make adjustments to avoid or reduce potential negative impacts on bat species that could be concentrated in these areas.

6.3.2 Operational Avoidance and Minimization Options

Operational avoidance and minimization options may be considered: 1) as a proactive, voluntary measure if siting and pre-construction assessments indicate there may be a risk of impact to individual bats, or; 2) if observed fatalities exceed expected fatalities. These options can be implemented as part of an adaptive management strategy in conjunction with a monitoring plan, and may be recommended by current provincial guidelines (Appendix I). Options that may be considered include instituting general avoidance measures or employing operational avoidance and minimization methods (i.e., deterrents, curtailment, or integrated detection-deterrent or detection-avoidance systems).

Various general avoidance measures designed to reduce the attractiveness of areas near turbines to bats or to minimize the effects of post-construction activities on bats are considered industry best practice and can be considered during the wind energy operations. Although the effectiveness of these measures has not been rigorously evaluated they are commonly recommended by regulatory agencies (e.g., [125]). These options are typically less costly to operators than are operational minimization measures and can potentially minimize the need for further operational mitigation. Section 4.2.1 summarizes some of the general avoidance measures that may be considered. Additional BMP recommendations can be consulted in various planning guidelines that are publicly available [73], [277], [278].

Deterrents may be considered as stand-alone minimization options or can be used concurrently with other minimization options (e.g., curtailment). Technological approaches to deterring bats have not yet undergone complete effectiveness testing and are not yet practicable for widespread use. However, wind operators can work with technology developers and research institutions as appropriate, with the aim of identifying and testing effective and feasible methods that are suitable for commercial applications. Section 4.2.3 and Appendix G provide an overview of technologies currently under development.

Curtailment, defined as altering turbine operations at one or more turbines when bats are thought to be at higher risk of collision, has become the most commonly used approach to minimizing impacts to bats. Strategic options typically include altering turbine cut-in speeds to those above manufacturer-recommended speeds and feathering blades below cut-in speeds. Expected outcomes from published and unpublished reports, and regional considerations based on provincial agency guidelines are presented in Section 4.2.2, Appendix F, and Appendix I. Several automated modules designed to curtail turbines based on temporal and environmental conditions are available from turbine manufacturers (e.g., Batshield system from Gamesa[7]) but a full discussion of these modules is beyond the current scope of this Review. Automated detection-minimization systems based on bat activity levels are also in development or commercially available (Sections 4.2.3.2 and 4.2.3.3). Although these integrated systems have not undergone extensive independent testing for effectiveness, the intention is to optimize curtailment timing so that impacts to bats and production loss may both be minimized.

Research and monitoring plans can be implemented to assess the effectiveness of any minimization strategy, and are most effective when targeted towards answering specific questions pertaining to effectiveness. Employing a flexible, research-based approach will thus strengthen the adaptive management process, facilitate learning, and improve bat conservation at a multi-project (e.g., regional) scale.

6.3.3 Compensation and Offset Options and Considerations

There are a number of compensation and offset options that may be considered if there is concern that a project still may cause impacts to bats after avoidance and minimization measures have been implemented. Prior to consideration of compensation and offset options, developers and operators may consider the potential for WNS presence in the vicinity of a project (see Appendix D). Several additional options may be available to compensate or offset potential bat impacts at these projects. These compensation and offset options are summarized in Section 5.4. Note that although not specifically identified as a limitation, partnerships with landowners will likely be necessary to implement many of these options and may not always be feasible.

Developers and operators can draw upon current knowledge of the range of WNS in Canada, as well as which species have been found to be susceptible to the disease (Section 5.2, Appendix D).

[7] http://www.windpowerengineering.com/featured/looking-our-for-our-avian-neighbors/

Potentially-affected species may require greater consideration at projects that: 1) are in the WNS range, and 2) contain habitats where these species are likely to occur. Developers and operators should also be aware that the WNS range has been expanding rapidly, including recent confirmation in northwestern and southwestern U.S. (Washington and Texas; Appendix D). The most current WNS range information may be consulted (see Appendix D)[8], with the acknowledgement that current distributions are dynamic and do not necessarily represent future conditions. Some bat populations have been severely impacted by WNS. The presence of WNS in bat populations near a project may offer compensation and offset opportunities focused on these species.

6.3.4 Post-Construction Monitoring Options

Adaptive Management is an iterative process, and effective monitoring is a critical component to that process [259]. To this end, operators typically include a monitoring plan to determine fatality levels during a representative sampling period after any avoidance or minimization measures are implemented. Monitoring to determine the effectiveness of specific measures is most valuable when spread among multiple projects [261], so that overall learning goals are met without individual projects requiring extensive, long-term monitoring obligations. Primary decision options when developing monitoring plans include choice of a fatality estimator and the spatial and temporal scope of monitoring protocols. Results from fatality monitoring will determine if observed fatality rates exceed those that were expected for a project, and thus will drive the iterative process of the adaptive management framework (Figure 6-4). Results will also; 1) identify which avoidance and minimization methods are most effective, 2) reduce uncertainty associated with their effectiveness, and 3) ultimately improve mitigation options available to the industry as a whole.

Fatality monitoring design is often governed by regulations at the Provincial level; however, to the extent possible, monitoring should be designed to answer questions driven by the adaptive management plan. Different designs may be needed, for example, to monitor effectiveness of avoidance and minimization measures than to estimate overall fatality rates. The probability of detection for bat carcasses is generally low, and it is useful to conduct prospective analyses prior to monitoring to estimate the power of a given design to answer the questions raised by the adaptive management plan.

As discussed in Section 3, the choice of fatality estimator will influence monitoring schedules, is contingent upon varying assumptions, and will affect the inferences that can be made regarding fatality rates. It should be noted that some existing provincial guidelines require the use of specific estimators as well as specific fatality monitoring protocols (e.g., duration, intensity; Appendix I). Ontario, for example, requires use of the MNRF adapted estimator, in combination with carcass searches every 3 to 4 days, regardless of the specific circumstances of the project. Decisions about which estimator to use and the structure of monitoring protocols, however, will be most effective if they are based on project-specific conditions, consider the benefits and limitations of each estimator, and are focused on project goals and addressing specific hypotheses. Finally, as stated previously in this document, a primary objective of adaptive management monitoring is to reduce scientific uncertainty, and when this uncertainty is reduced to some acceptable level it may be feasible to reduce or eliminate monitoring within and across projects [261].

[8] https://www.whitenosesyndrome.org/resources/map

6.4 Summary

The adaptive management framework presented in this chapter was developed to summarize the considerations, options available, and scientific evidence associated with each of the decision points inherent in the process of wind energy project siting and operations. It is meant to serve as a simplified tool that broadly identifies each set of options, links to the more detailed assessments provided in Sections 2 to 5, and refers to the large body of information published by researchers and others that can help inform decisions. By providing the most current information available, the framework should facilitate discussions among industry, regulatory agencies, and environmental NGOs about the best ways to proceed with individual projects, as well as how to work together to identify best practices that are both effective and practicable.

7 CONCLUSIONS

The aim of this document has been to objectively summarize the best scientific and practicable information available with respect to wind energy and bats. It is expected that the Review will serve as an information source for the wind industry as well as a mechanism for information-sharing among industry, regulatory agencies, environmental NGOs, and public stakeholders. The adaptive management framework presented in the Review can be viewed as a generalized process by which decisions for individual projects can be made, but also as a method for improving predictions about how management decisions will affect bats. Use of an adaptive management framework will ensure that decisions and recommendations made at the project-level are aimed at high-level conservation and learning goals, and flexibility is a key component to this process. As a result, strategies for avoiding, minimizing and compensating for potential bat impacts will become increasingly effective, and decision-makers employing or recommending these measures will have increased confidence in results. It is also expected that by taking an adaptive management approach, the industry and other stakeholders can decrease the need for intensive monitoring at individual projects as scientific uncertainty is reduced over time.

Key conclusions from this comprehensive assessment are summarized in Table 7-1.

Table 7-1 Key Review Conclusions

Subject Area	Key Conclusions
Pre-Construction Avoidance	• Little scientific evidence is available concerning the effectiveness of various siting and pre-construction avoidance measures commonly recommended by regulatory agencies and adopted by the industry, including options for setbacks from preferred habitat and other micro-siting considerations. • Current pre-construction avoidance measures are based on scientific understanding of general ecology and phenology of bat species. • Because pre-construction avoidance measures have the potential to reduce risk to bats and typically cost less than avoidance, minimization, and mitigation measures applied at the operational stage, these options may be considered and applied when practicable. • An adaptive management approach by the wind industry and other stakeholders is expected to improve confidence in the effectiveness of some of these measures over time.
Operational Avoidance	• General avoidance measures are typically less costly than operational minimization options and are based on a vast body of bat ecology literature. Further research regarding the effectiveness of these measures is expected to improve avoidance strategies adopted by the wind industry. • Although several operational deterrents are in development and showing some promise of effectiveness, no proven methods are commercially available. • The most promising deterrent technologies to date are acoustic deterrents. Additional technologies under development include texturized coatings and low-level UV lighting. • Using an adaptive management framework will allow industry, regulatory agencies, and academics to work cooperatively to accelerate the identification and commercialization of effective bat deterrent measures.

Table 7-1 Key Review Conclusions

Subject Area	Key Conclusions
Operational Minimization	• In general, operational curtailment and feathering has been shown to be effective for reducing bat fatalities, however, the optimal strategy for minimizing impacts to bats is unknown, particularly with respect to the benefits of raising cut-in speeds above 4.5 m/s. • Reported effectiveness estimates from raising cut-in speeds to 4.5 m/s or greater ranged from a 47 to 96% reduction in bat fatalities. Results varied within and among curtailment strategies (e.g., feathering vs. free-wheeling, specific cut-in speed). • Several integrated monitoring-minimization systems are commercially available and could minimize costs by providing more targeted curtailment, however these systems require further independent evaluation. • Emerging monitoring technologies, such as IR and improved species identification systems, are in the early stages of effectiveness testing, but are not yet fully commercialized. The industry and regulatory agencies have the opportunity to cooperatively evaluate the potential for these new monitoring approaches to improve operational minimization strategies and systems. • Through an adaptive management approach, the industry, regulatory agencies, academics and other stakeholders can work cooperatively to identify the thresholds, conditions, and combined methods (e.g., with avoidance measures) that can effectively minimize impacts to bats while maintaining project sustainability. As more is understood about the effectiveness of various minimization measures, monitoring requirements at individual projects are expected to decrease over time.
Fatality Estimation	• Fatality estimation requires appropriate decisions regarding monitoring protocols, search parameters, and statistical estimators. • The most commonly used fatality estimators rely on varied assumptions and are affected differently by variables including search frequency, scavenger trial and searcher efficiency trial methods, and search area. • Flexibility should allow individual projects to identify which monitoring designs and estimators, based on project-specific conditions, are most likely to produce unbiased fatality estimates. • Fatality estimation provides a means of informing the adaptive management process regarding the need for and effectiveness of avoidance and minimization measures.
Compensation and Offsets	• Compensation and offset options may be appropriate in some circumstances. • Options may include habitat protection or enhancement, reducing the impacts of WNS, and/or conservation banks. • These options are generally most effective when they are targeted to specific species. • Compensation and offsets can be considered during all project phases (e.g., Siting, Operations). • Compensation and offsets may be considered as part of an overarching adaptive management strategy aimed at reaching bat conservation goals, and assessment of these measures offers additional opportunities for partnerships and research efforts.

Table 7-1 Key Review Conclusions

Subject Area	Key Conclusions
Adaptive Management Framework	• Adaptive Management is an iterative learning process that improves the effectiveness of bat conservation measures over time. • The learning process has high utility for individual wind projects, but is most effective when aimed at broad-scale conservation goals and informed by information from multiple wind energy projects as well as by external research efforts. • The underlying goals of adopting an adaptive management process are to facilitate renewable energy development thus reducing the impacts of climate change, maintain stable populations of bats in Canada, and reduce scientific uncertainty with respect to conservation strategies. • As more is learned, mitigation and monitoring strategies will become more targeted, cost effective, and beneficial to bats. • With a reduction in scientific uncertainty, it is expected that the need for intensive monitoring at individual projects will also be reduced. • As adaptive management implies, there needs to be a willingness by both operators and regulators to implement innovative strategies to maximize reductions in bat fatalities; the framework is most effective when not constrained by “boiler plate” mitigation, which may have limited potential to provide benefits.

The wind industry, regulatory agencies, environmental NGOs, and other stakeholders have a shared goal of limiting the negative effects of climate change on wildlife and humans caused by the burning of fossil fuel. Climate change is now recognized as a primary threat to bat species worldwide [279]. Species at northern latitudes may be particularly at risk, and species susceptible to WNS, one of the greatest threats to North American bats, are expected to suffer due to potential climate-induced proliferation of the disease [279]. In Canada, the continued shift towards renewable, environmentally sustainable energy sources will ultimately prove beneficial to bats, particularly if a science-based, adaptive approach is taken by all stakeholders. It is the industry’s intention to continue to improve on current measures to avoid and minimize bat fatalities associated with wind energy facility operations, and to help the country meet its long-term bat conservation goals.

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9 GLOSSARY OF TERMS

Adaptive management – A structured, iterative process by which recurrent decisions are made based on information gained from the results of prior management actions [259].

Attenuation– The absorption by the air of a sound wave, which is dependent on frequency, humidity, and distance.

Avoid – To not take an action or parts of an action to avert the potential effects of the action or parts thereof [125].

Barotrauma – Injury caused by a change in air pressure, typically affecting the ear or lungs. Although initially proposed as a significant source of bat fatalities at wind facilities [280], more recent research indicates that barotrauma is rare and represents a minor etiology (i.e., cause of death) [281].

Best management practices (BMP) - Methods that have been determined to be the most effective, practicable means of avoiding or minimizing significant adverse impacts to individual species, their habitats or an ecosystem, based on the best available information [125].

Bias – Difference between an estimator's expected value and the true value of the parameter being estimated.

Bleed-through – Circumstance in which a carcass not detected by a searcher persists until a subsequent search, making it available for future detection.

Carcass – Body of a dead bat.

Carcass persistence – The amount of time a bat carcass remains within a search plot prior to removal by scavengers or through decomposition. Expressed as either number of days or as a probability of persistence for a set time.

Common species – Describes population status of a species. Common species have high abundance in an environment, habitat, or area and are therefore frequently encountered.

Compensation or compensatory mitigation – Compensation for project-induced losses to wildlife resources (i.e., bats and bat habitats). Substitution or offsetting of fish and wildlife resource losses with resources (land/monetary or other actions) considered to be of equivalent biological value [125].

Conservation bank - Conservation banks are permanently protected lands or protected areas that are managed for species that are endangered, threatened, or otherwise considered species-at-risk. Conservation banks function to offset adverse impacts to these species and their habitats that have occurred elsewhere. In addition, conservation banks can be set aside for proponents or developers to draw upon to mitigate future impacts.

Cumulative impacts (Cumulative effects) – Effects that are likely to result from the incremental impact of the project in combination with other past, present, or approved future projects or activities.

Curtailment – The act of limiting the supply of electricity to the grid during conditions when it would normally be supplied. This is usually accomplished by cutting-out the generator from the grid and/or feathering the turbine blades [125]. Bat-targeted curtailment is defined for this Review as altering turbine operations when bats are most at risk (e.g., migratory periods, from sunset to sunrise), as a tool for reducing impacts to bats.

Cut-in speed – The wind speed at which the generator connects to the grid and begins producing electricity. It is important to note that turbine blades may rotate at full RPM in wind speeds below cut-in speed [125].

Decision tree – A tool used to inform adaptive management decisions and part of a structured, directional decision making process. A decision tree contains an explicit sequence of discrete decision nodes and conditional nodes to help guide decision-makers through the decision process.

Deterrent - A measure used to discourage bat species from the rotor-swept zone of wind turbines during operations with the aim of reducing the risk of collision.

Fall zone – The area around a turbine in which carcasses of bats struck by the blades fall. The fall zone may vary according to the size of the turbine and the size of the carcass.

Fatality – Process producing the death of an individual bat.

Fatality estimate – Estimate of bat fatality after adjustment for potential bias factors including imperfect searcher efficiency and carcass persistence.

Fatality estimator – A statistical analysis used to estimate fatality rates by adjusting observed counts of carcasses for sources of bias (e.g., carcass persistence, searcher efficiency).

Fatality rate – The ratio of the number of individual deaths to some parameter of interest such as megawatts of energy produced or the number of turbines in a wind energy facility, within a specified unit of time [125].

Feathering or feathered – Adjusting the angle of the rotor blade parallel to the wind for the purposes of slowing or stopping blade rotation [125].

Free-wheeling – When turbine blades are allowed to rotate freely and do not produce electricity but may still rotate at speeds up to 10 RPM.

Hibernaculum (plural hibernacula) – A shelter (e.g., caves or abandoned mines) in which dormant bats will roost over a period of time (usually winter).

Hibernation – An extended period of inactivity and metabolic depression (see Torpor) that is usually seasonal (i.e., winter).

Impacts - A strong effect generally used to refer to negative effects that may result from wind energy development (as defined for this Review).

Life-history – The sequence of fitness‐related events and processes occurring during the life of an individual, such as growth, survival, and reproduction.

Manufacturers' cut-in speed – The manufacturers' set or default wind speed at which a wind turbine generator connects to the grid (see Cut-in speed). For most contemporary turbines, this speed is between 3.0 and 4.0 m/s.

Minimize – To reduce to the smallest practicable amount or degree [125].

Mitigation – Avoiding or minimizing significant adverse impacts, and when appropriate, compensating for unavoidable significant adverse impacts [125]. Sometimes referred to as operational mitigation if occurring during facility operations.

Mitigation hierarchy – Method by which project developers or operators sequentially avoid, minimize, restore, and offset any predicted impacts [262], [263].

Monitoring - A systematic program of observing and recording ecological data. Monitoring at wind energy facilities is conducted to observe change in target variables (e.g., bat activity or fatalities) over time.

Mortality – Relative frequency of deaths in a population.

Near-commercial – Not currently available for purchase but undergoing field testing.

Offsets - The preservation, enhancement, restoration and/or establishment of a resource to compensate for or offset unavoidable adverse impacts to the resource elsewhere (see Compensation or compensatory mitigation).

Operational avoidance and minimization – Measures designed to reduce bat fatalities at operational wind energy projects post-construction. Some researchers also use the term operational mitigation for these measures.

Original equipment manufacturer (OEM) –Manufacturer or vendor of the equipment supplied to a wind energy facility.

Power purchase agreement (PPA) – A contract to buy electricity generated by a wind energy facility.

Proportion of carcasses in sample area – The proportion of the distribution of carcasses around a turbine that is sampled by a search. This proportion varies with the size of the search plot and the degree to which unsearchable areas are present within plots.

Range - Species distribution; the geographical area within which a species can be found.

Riparian – having to do with the banks and vicinity of a river or stream.

Rotor-swept area (RSA) – The area of the circle or volume of the sphere swept by the turbine blades at an individual turbine [125].

Rotor-swept zone (RSZ) – The altitude within a wind energy facility which is bounded by the upper and lower limits of the rotor-swept area and the spatial extent of the facility [125].

Searcher efficiency – The probability that a searcher performing fatality surveys will observe a carcass present within the search area.

Stable – A state in which a population of a species remains unchanged over time (i.e., finite rate of increase near 1.0) and is not at risk of extinction or significant decline.

Stakeholder – A person, company, or group, with an interest or concern in the wind industry or the conservation of bats.

Supervisory control and data acquisitions (SCADA) system - An industrial automation control system at the core of many modern industries, including utility-scale wind energy facilities. Wind-farm SCADA systems use software programs to monitor and process data and control turbines (e.g., cut-in speed and feathering) in order for operators to control and improve efficiency of wind turbines.

Sound pressure level (SPL) - The original transmitted power of a sound, measured as the difference between the pressure produced by a sound wave and the barometric (ambient) pressure at the same point in space.

Sustainable - Able to last or continue indefinitely without significant depletion of resources (e.g., animal populations or finances).

Torpor – A state of physiological inactivity in an animal, with reduced metabolism and body temperature, to survive periods of colder temperatures or reduced food availability (see Hibernation).

Uropatagium - The membrane between the legs of a bat.

Volant (or volancy) – Capable of flight.

White-nose syndrome (WNS) – Fungal infection caused by *Pseudogymnoascus destructans* (Pd) that primarily affects cave-roosting bats. The infection is fatal to most bats that contract the fungus.

10 APPENDICES

APPENDIX A – BAT SPECIES PROFILES

The bat species profiles below summarize species status in Canada, key identification features, range, approximate population numbers in Canada, habitat preferences, and foraging and breeding behaviour. Spatial data sources for all species range maps were obtained from the USGS and BCI, and may not reflect the most recent occurrence data for all species [21], [282]. Note that maps are based on occurrence data collected over a 100- to 150-year period and may represent either resident, migratory, or stray status [282]. Additional range maps are included for the three SARA-listed species (little brown myotis, tri-colored bat, and northern myotis), the three species with the highest fatality rates at wind energy facilities (eastern red bat, hoary bat, silver-haired bat), and one species that may be at risk due to behaviour [4], but only represents approximately 12% of fatalities across Canada (big brown bat [275]).

Big Brown Bat (*Eptesicus fuscus*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	S4S5 (Apparently Secure to Secure)	-
	BC	S5 (Secure)	-
	MB	S4S5B (Apparently Secure to Secure – Breeding)	-
	NB	S2? (Imperiled – Inexact or Uncertain)	-
	NL	-	-
	NS	-	-
	NT	SU (Unrankable)	-
	NU	-	-
	ON	S4 (Apparently Secure)	-
	PE	-	-
	QC	S4 (Apparently Secure)	-
	SK	S5 (Secure)	-
	YT	SNR (Unranked)	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

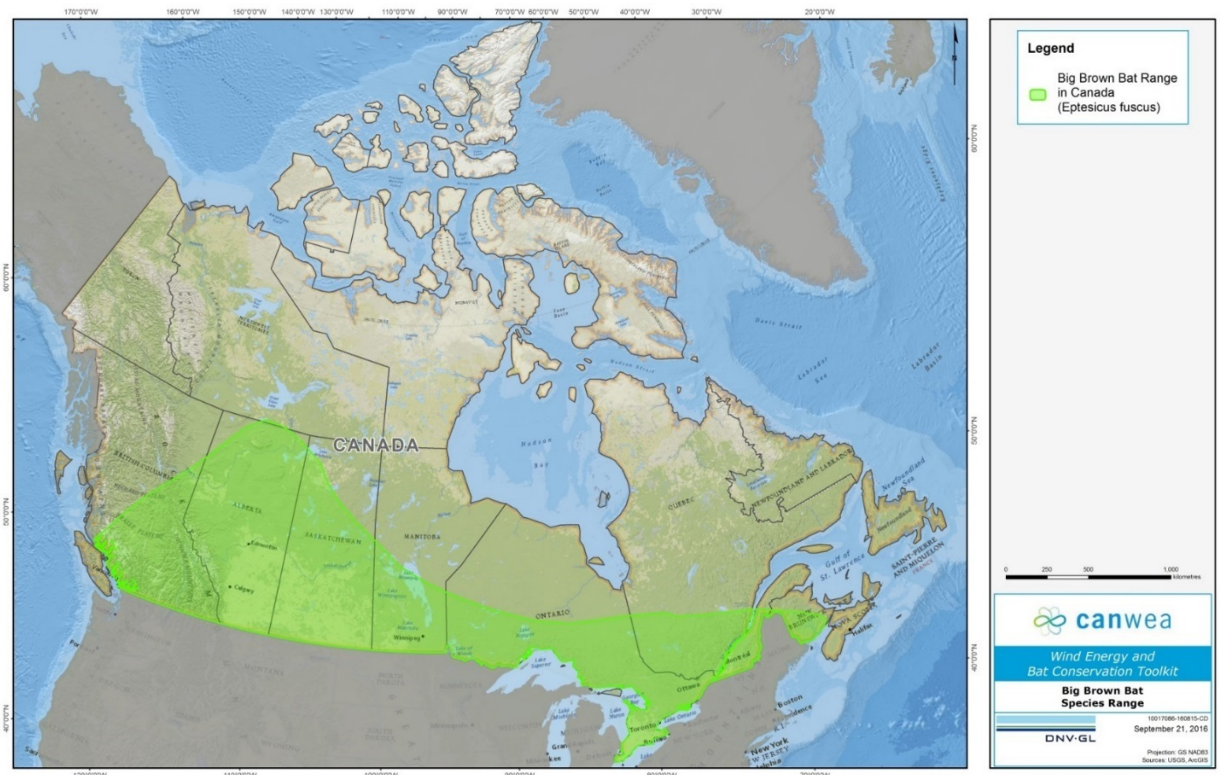
Key Identification Features

In Canada, the big brown bat (*Eptesicus fuscus*) typically has reddish to dark brown dorsal fur with a distinctly lighter underside; however, some individuals may be almost blonde in colour [19], [29]. The dorsal fur extends approximately one-third of the way down uropatagium (the membrane between the legs) [19]. The snout, wing membranes, and ears are black and hairless, and the ears are short [19]. Key identification features of big brown bat include [19], [29]:

- Ears are short, black and entirely hairless;
- Fur on body is reddish to dark brown on back, with a lighter underside;
- Forearm length: 40 to 51 mm (mean = 45 mm);
- Body length: 83 to 130 mm;
- Ear length: 13 to 20 mm; and
- Wingspan: 32 to 39 cm.

Range

The big brown bat is among the most widespread of all bat species, ranging through southern Canada from coast to coast and southwards to northern South America, including many islands (i.e., West Indies and Vancouver Island) [19]. There are also isolated reports from central Alaska, the Yukon, and the southwestern part of the Northwest Territories [19], [36].



Population Numbers

Big brown bat is a common species throughout most of its distribution, although it is uncommon to rare at the northern extents (Yukon and Northwest Territories) [19]. The population size is unknown, although it is suspected to be increasing due to the increase in the number of houses and other structures [36]. Female big brown bats will form maternity colonies which can vary from 5 to 700 individuals [19], [36].

Habitat Preferences

The big brown bat is a generalist in its habitat preference, as it is found in habitats from forests to meadows to agricultural and urban areas [19], [21]. Big brown bat hibernates in caves, abandoned mines, deep rock crevices, heated buildings, and also in tree hollows in warmer areas. They prefer cool temperatures and can tolerate a wider range of temperatures than many other bat species [36].

Big brown bat breeding and day roost habitats are similar, and include tree cavities, under loose bark, in rock crevices, and in buildings or structures [19]. It is believed that the distance between summer roosts and hibernacula is typically not more than 80km [19]. Big brown bats show high roost fidelity, especially to their maternity and hibernation sites in buildings [19]. Big brown bats are the most abundant species in forested, urban parks [284]. The big brown bat is likely more adaptable to urban environments due to its ability to use anthropogenic structures as roosts during the day.

Foraging and Breeding Behaviour

Big brown bats begin foraging after sundown and will continue throughout the night, although rainy nights or temperatures below 15 °C will delay or cause them to forgo their emergence [19]. They will usually go to water to replenish their liquids and then begin to hunt. The big brown bat is insectivorous, primarily preying on beetles, but will also eat other flying insects such as moths, flies, wasps, flying ants, lacewing flies, and dragonflies [36]. They are generalists for foraging behaviour, showing little preference for feeding location (i.e., over water vs. land) [21]. Big brown bats are aggressive in defending their foraging space and will often exclude or attempt to exclude other bats and even birds from foraging in their territory [19].

Female big brown bats form maternity colonies to rear their young and the size of these colonies can range from 5 to 700 individuals, but typically contain fewer than 100 females and occasionally a few males [19], [36]. Mating usually occurs in the fall before hibernation and females will store the sperm until they ovulate in the spring [19].

Brazilian Free-tailed Bat (*Tadarida brasiliensis*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	SNA (Not Applicable)[3]	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].
[3] Ranking was applied prior to confirmed species presence in 2017.

Key Identification Features

Brazilian free-tailed bat (*Tadarida brasiliensis*) is a medium-sized bat species, with reddish-brown fur and a characteristic mouse-like tail that protrudes beyond the uropatagium [37]. Brazilian free-tailed bat has broad ears and long, narrow wings which are well-adapted for the bat's aerial lifestyle [285]. Key identification features of Brazilian free-tailed bats include [37]:

- Ears are relatively broad and black in colouration;
- Fur on body is short, velvety, and reddish to black in colouration;
- Forearm length: 42 mm;
- Body length: 95 mm;
- Ear length: 19 mm; and
- Wingspan: 28 cm.

Range

Brazilian free-tailed bat is widespread throughout South, Central, and North America [21]. However, the species has only recently been recorded on Salt Spring Island in British Columbia and it is possible that local reproductive colonies may exist elsewhere in British Columbia [22].

Population Numbers

Brazilian free-tailed bat is considered common throughout its range in the western and southern U.S. [21]. Texas has the densest concentrations of Brazilian free-tailed bat and it is estimated that 100 million bats form maternity colonies in Central Texas each year [21]. Population size and trends are unknown in British Columbia [20]. Although population trend across most of its range is considered stable, the species may be declining due to diseases, habitat loss (e.g., disturbance to maternity colonies), and pesticides [37], [286].

Habitat Preferences

Brazilian free-tailed bat is found in a wide variety of habitats from desert communities to pinyon-juniper woodland and pine-oak forests (up to 2,743 meter elevations) [21]. Brazilian free-tailed bat forages in a wide range of habitats including over open agricultural fields and over woodlands and forests [21]. Maternity colonies are formed in limestone caves, abandoned mines, under bridges, and in buildings; however, smaller colonies have also been found in hollow trees [21]. Little is known about the species foraging and roosting habitat preferences within British Columbia.

Foraging and Breeding Behaviour

Brazilian free-tailed bat emerges for nightly foraging at dusk [37]. The species has been observed reaching altitudes of 305–3,048 meters to forage on cotton boll worm moths, army cut-worm moths, June beetles, leaf beetles, and other species of migratory agricultural pests [21], [37]. Agricultural pest insect species comprise a substantial portion of the Brazilian free-tailed bat diet and suggests this species provides valuable natural pest control [21], [287].

Brazilian free-tailed bats give birth to a single pup in mid-June [37]. The young can fly and forage on own approximately four weeks after birth [37]. Brazilian free-tailed bat maternity colonies are large, and can contain millions of individuals [21], [37].

California Myotis (*Myotis californicus*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	S4S5 (Apparently Secure to Secure)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

California myotis (*Myotis californicus*) is a small bat species, with fur colour that ranges from dull blackish brown (coastal populations) to light reddish brown (inland populations) [19]. California myotis has slightly paler ventral fur and black ears, snout, and wings [19]. California myotis has relatively long ears, small hind feet, and a keeled calcar [19]. Key identification features of the California myotis include [19], [29]:

- Ears are relatively long and black in colouration;
- Fur on body is dull blackish brown to light reddish brown;
- Forearm length: 32 to 35 mm;
- Body length: 74 to 95 mm;
- Ear length: 11 to 15 mm; and
- Wingspan: 22 to 23 cm.

Range

California myotis is found throughout western North America, ranging from southern Alaska through British Columbia and the western United States south to Guatemala [21], [40]. In Canada, California myotis is found in British Columbia from the Queen Charlotte Islands to near the Alberta border [19].

Population Numbers

California myotis is considered common throughout its Canadian range in British Columbia [19]. The global population trend of California myotis is unknown [102].

Habitat Preferences

California myotis is found in a range of habitats, including arid grasslands, coastal rainforests, and montane forests (up to ~1,300 m elevation) [19]. In the dry interior, California myotis is typically found near water where prey is more abundant [19]. California myotis also forages in a wide range of habitats including over open areas, along forest edges, and over water [40]. California myotis roosts under tree bark, in tree and rock crevices, under bridges, and in buildings [19], [21]. California myotis prefers maternity roost sites consisting of large, dead trees near water and foraging habitat [19]. There are no known hibernation sites for California myotis in British Columbia, but it is likely that some individuals hibernate in buildings, caves, or old mines near summer ranges [19].

Foraging and Breeding Behaviour

California myotis emerges for nightly foraging around sunset, and conducts two nightly foraging sessions with a roosting break in the middle [19]. California myotis forages within 1 to 5 m of the ground [40]. In Canada, California myotis forages primarily on caddisflies, also ingesting some moths, flies, and beetles [19]. California myotis is known to forage on warmer winter days [19], [40].

Little information is available on California myotis breeding behaviour [19]. In Canada, mating occurs in the fall, and a single young is born between late June and early July [19], [40]. The young can fly approximately four weeks after birth [19]. California myotis maternity colonies are small, typically consisting of up to 25 individuals [40]. California myotis regularly changes its roosting sites [19], [21].

Eastern Red Bat (*Lasiurus borealis*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	S1 (Critically Imperiled)	-
	BC	S4 (Apparently Secure)	-
	MB	S3B (Vulnerable – Breeding)	-
	NB	S2? (Imperiled – Inexact or Uncertain)	-
	NL	-	-
	NS	S2? (Imperiled – Inexact or Uncertain)	-
	NT	-	-
	NU	-	-
	ON	S4 (Apparently Secure)	-
	PE	-	-
	QC	S3 (Vulnerable) / Likely To Be Designated	-
	SK	S4B, S5M (Apparently Secure – Breeding, Secure – Migrant)	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

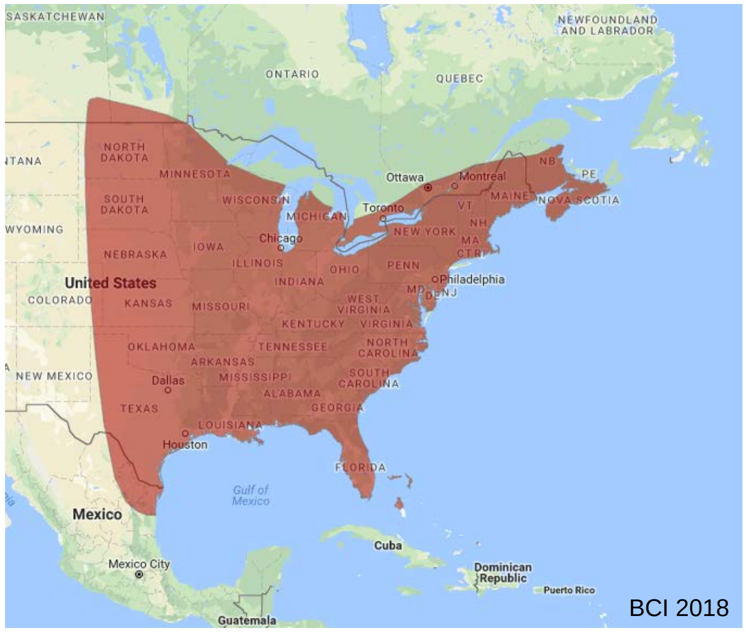
Eastern red bats (*Lasiurus borealis*) have long, silky fur that is primarily sandy orange to brick red that is tipped with black or white on its back and has slightly paler hairs on its underside [19]. These identification features serve to distinguish this bat from any other Canadian bat species [19]. The wing membranes are dark in appearance and the portions of the ears and snout that are hairless are reddish [19]. The uropatagium of eastern red bats is quite long and furry on the upper side [19]. The males have a stronger colouration than the females [19]. Key identification features of eastern red bats include [19], [29]:

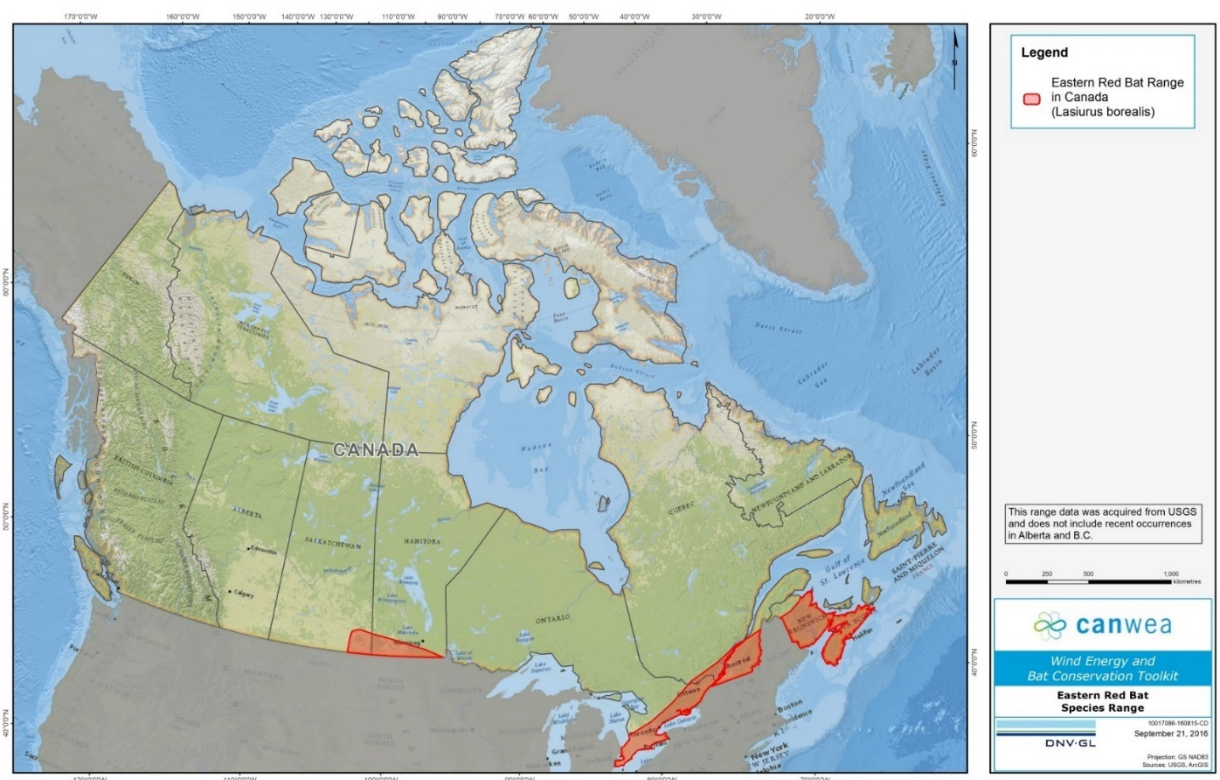
- Uropatagium has fur;
- Ears are round and entirely flesh-coloured;
- Fur on body is sandy orange to brick red in colouration, with silver tips (not always evident);
- White throat patch;
- Forearm length: 32 to 50 mm (mean = 40 mm);
- Body length: 87 to 120 mm;
- Ear length: 10 to 13 mm; and
- Wingspan: 28 to 33 cm.

Range[9]

In Canada, the eastern red bat is found along the southern edge of Manitoba and Ontario and a small southern portion of Saskatchewan, as well as within New Brunswick, Nova Scotia and Prince Edward Island. In the United States, eastern red bat is widespread across the central and eastern portion of the country and extends into a small portion of Mexico [21]. Eastern red bats are also occasionally encountered further west in Canada, despite not being included in the approximate range map shown below. Although the map for eastern red bat does not show the species occurring in Alberta, bats have been found as fatalities at wind energy facilities in the province [9], [23]. This and other evidence [24] suggests that the species range includes Alberta, British Columbia, and likely portions of western Saskatchewan.

[9] The approximate range map data were collected from BCI and do not include recent eastern red bat occurrences in Alberta and British Columbia.





Population Numbers

Population numbers for the eastern red bat are generally unknown, although they are believed to be one of the most abundant tree-roosting bats within the United States [45], [103]. Although they are considered to be abundant in the United States, there has been evidence that suggests that numbers are declining by up to 85% [19], [104]. This evidence is based on a report by Winhold et al. 2008 which examined the change in the assemblage of bats in southern Lower Michigan. This report paired netting surveys conducted with similar techniques but separated by 12 to 26 years and found that the amount of eastern red bats captured per night decreased by 52 to 85%. Despite compelling information, this single study conducted in a localized geographic area should not be considered representative of the population as a whole without considerable further studies on population numbers and abundance within North America.

Habitat Preferences

Eastern red bats roost within the foliage of deciduous or sometimes evergreen trees [103]. They prefer mixed hardwood forests and will roost from ground level up to the highest canopy, depending on weather conditions [19]. Eastern red bat is generally associated with contiguous forests with limited openings. Relative abundance of eastern red bats, for example, has been shown to be positively related to area of contiguous forest [288]. However, a positive relationship to the degree of forest fragmentation, independent of total forested area, has also been demonstrated [288] and eastern red bats have shown a positive response at some sites to selective logging that opens up coniferous forest canopies [231]. Eastern red bats will hang from the branches, closer to the outside of the canopy and often look like dead leaves or conifer cones [19], [103].

Preferred roosting sites provide cover to the species from the sides and above, but also have an open flight path below [19]. Eastern red bat forage in clearings at heights from ground level to tree tops, and is known to stay within the same foraging area as long as food is readily available. Swarming activity of eastern red bat was also observed during a study of 17 abandoned mines and eight caves in Nova Scotia in late August and early September [289].

The eastern red bat migrates to its hibernation location, which for most is in the southeastern United States. It hibernates under bark, in leaf litter, or in trees as long as it is not exposed to elements below 0 °C [19].

Foraging and Breeding Behaviour

Eastern red bats are a primarily solitary species when they are roosting [19], [103]. Eastern red bats are a primarily solitary species when they are roosting [19], [103]. They have been known to travel in small groups during migration, although males and females migrate at different times [19].

Within Canada, the eastern red bat typically emerges to forage a half-hour after sunset and will be out for two foraging periods. Insects within the 5 to 20 mm range are its food source and it has a preference for moths, but will also consume beetles, lacewings, flies, flying ants, termites, crickets, cicadas, and ground-beetles [19]. The eastern red bat uses it tail in a cupped fashion to catch prey and then transfer it to its mouth mid-flight [19].

Eastern Small-footed Myotis (*Myotis leibii*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	-	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	S2S3 (Imperiled to Vulnerable)	Endangered
	PE	-	-
	QC	S1 (Critically Imperiled) / Likely To Be Designated	-
	SK	-	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

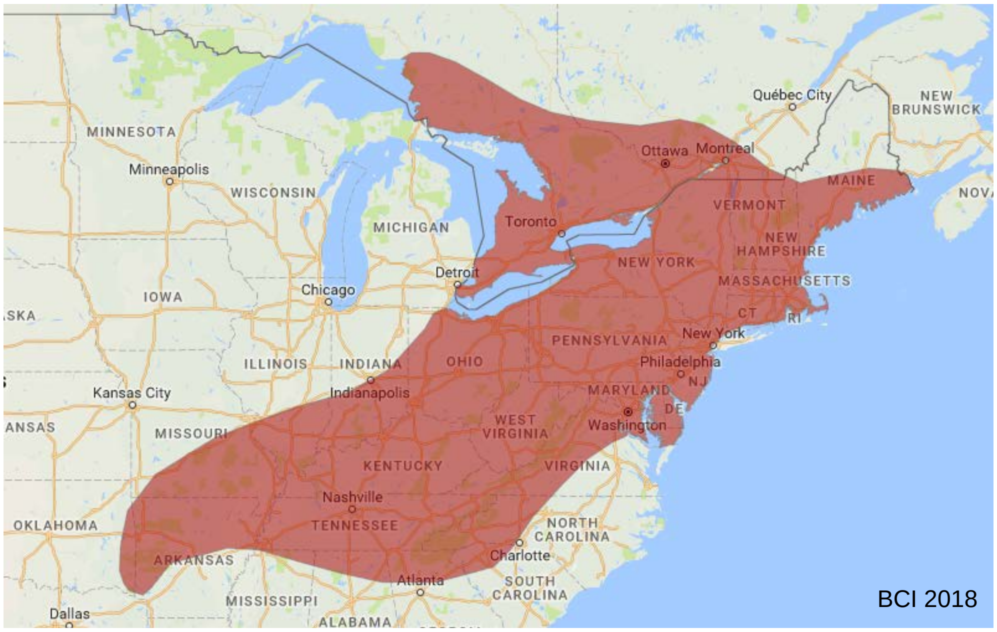
Key Identification Features

The smallest of the eastern Canadian bat species, eastern small-footed myotis (*Myotis leibii*) weighs between 3 to 5 g [19], [29]. Eastern small-footed myotis has golden brown fur and a distinct black mask across its face [29]. The ears, snout, and wing membranes are blackish in colour [19]. Eastern small-footed myotis has small feet which measure < 8 mm from the base of the heel to the tip of the digits [29]. The calcar of this bat is keeled (Fraser et al. 2007). Key identification features of eastern small-footed myotis include [19], [29]:

- Ears are black;
- Fur on body is golden brown;
- Black face mask;
- Forearm length: 29 to 33 mm (mean = 32 mm);
- Body length: 74 to 93 mm;
- Ear length: 11 to 14 mm; and
- Wingspan: 21 to 25 cm.

Range

Eastern small-footed myotis is limited to eastern Canada and the United States [19], [42]. Within Canada, eastern small-footed myotis is found in central Ontario and southern Quebec [19].



Population Numbers

Eastern small-footed myotis is thought to be the rarest bat species in eastern North America [19]. Eastern small-footed myotis population has experienced large declines due to white-nose syndrome; for example, bat populations at several hibernation sites in Ontario have decreased by more than 90% [41].

Habitat Preferences

Eastern small-footed myotis is typically found in deciduous or coniferous forests with hilly or mountainous terrain [19]. Limited data is available on the roosting preferences of eastern small-footed myotis; however, it is assumed that eastern small-footed myotis uses small crevices, including in anthropogenic structures [29]. Eastern small-footed myotis forages over both land and water at heights of 1 to 6 m [19], [42]. In winter, eastern small-footed myotis hibernates in caves and abandoned mines [29].

Foraging and Breeding Behaviour

Eastern small-footed myotis feeds on a wide variety of insects, including moths, beetles, flies, crickets, and spiders [19], [42]. Eastern small-footed myotis emits high frequency echolocation calls which allow them to forage in cluttered tree canopies [43]. Eastern small-footed myotis travels to multiple sites during a night to forage; sites can be up to 2 km from the roost [43].

Eastern small-footed myotis generally roosts alone, but maternity roosts can consist of 12 to 20 reproductive females [19], [42]. Eastern small-footed myotis reproduce during swarming at roost sites in late summer and autumn prior to hibernation [19], [29]. The female gives birth to a single pup between late May and early July of the following year [19], [29].

A cold-tolerant species, hibernation extends from late November to early April [19]. Eastern small-footed myotis prefers hibernacula with low humidity and can tolerate temperatures as low as –9 °C [19]. Eastern small-footed myotis travels short distances (approximately 20 km) between summer and winter roosts [19].

Fringed Bat (*Myotis thysanodes*)

Range		***Conservation*** [1]	***Legal*** [2]
Provincial	AB	-	-
	BC	S3 (Vulnerable)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		Data Deficient	Special Concern
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

The largest of the Canadian *Myotis* species, the fringed bat (*Myotis thysanodes*) has pale brown dorsal fur, a cream-coloured abdomen, and blackish ears and wings [19]. The characteristic feature of fringed bat is a fringe of stiff, short hairs on the outer edge of the uropatagium, which is visible to the naked eye [44]. This identification feature serves to distinguish this bat from any other Canadian bat species. The fringed bat has long ears, and its calcar is long and not keeled [46]. Key identification features of fringed bats include [19]:

- Uropatagium has a fringe of stiff, short hairs on the outer edge;
- Ears are long and black;
- Fur on body is pale brown on back and cream-coloured on abdomen;
- Forearm length: 40 to 45 mm;
- Body length: 88 to 93 mm;
- Ear length: 18 to 20 mm; and
- Wingspan: 27 to 30 cm.

Range

The fringed bat is found throughout western North America, from the northern limit of its distribution in south-central British Columbia through the western United States to Mexico [290].

The fringed bat is found throughout western North America, from the northern limit of its distribution in south-central British Columbia through the western United States to Mexico [290]. The Canadian portion of the fringed bat range comprises less than 5% of its global range [19].

Population Numbers

The population size and trends of the fringed bat are unknown [45], [46].

Habitat Preferences

Within Canada, the fringed bat is typically found in grassland, shrub-steppe, and open ponderosa pine forest habitats (primarily at 300 to 800 m elevation) [46]. Although fringed bat is rarely observed within the Canadian portion of its range, the fringed bat is regularly reported at a few sites within the Okanagan Valley and other valleys of the dry interior regions of British Columbia [45], [46].

A lack of data exists regarding the foraging and roosting habitat of the fringed bat in Canada; much of the available information is from studies conducted in the United States [46]. Fringed bat is known to roost in caves, tunnels, abandoned mines, rock crevices, and buildings [21], [44], [291]. In Canada, maternity colonies have only been recorded in buildings [19]. Although little is known about the fringed bat's foraging habitat in Canada, it is thought that fringed bat forages mostly in riparian habitats from 3 to 10 m above the ground [46].

Foraging and Breeding Behaviour

Active at night, fringed bats are gleaners, plucking their prey from the surface of vegetation [19], [44]. Fringed bat generally forages close to the vegetative canopy, within an area of approximately 4 km^2 [19], [291]. The fringed bat's diet is largely composed of beetles, moths, flies, and lacewings [46].

The fringed bat roosts in colonies of up to several hundred individuals in size [44], [290]. Females arrive at maternity colonies in early to mid-April, and young are born from mid-June to mid-July [46], [290].

Fringed bat is thought to migrate to southern over-wintering grounds, but little is known about its wintering habits [44], [290].

Hoary Bat (*Lasiurus cinereus*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	S2 (Imperiled)	-
	BC	S4 (Apparently Secure)	-
	MB	S3B (Vulnerable – Breeding)	-
	NB	S2? (Imperiled – Inexact or Uncertain)	-
	NL	SNA (Not Applicable)	-
	NS	S2? (Imperiled – Inexact or Uncertain)	-
	NT	SU (Unrankable)	-
	NU	-	-
	ON	S4 (Apparently Secure)	-
	PE	SNA (Not Applicable)	-
	QC	S3 (Vulnerable) / Likely To Be Designated	-
	SK	S5B, S5M (Secure – Breeding, Secure – Migrant)	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

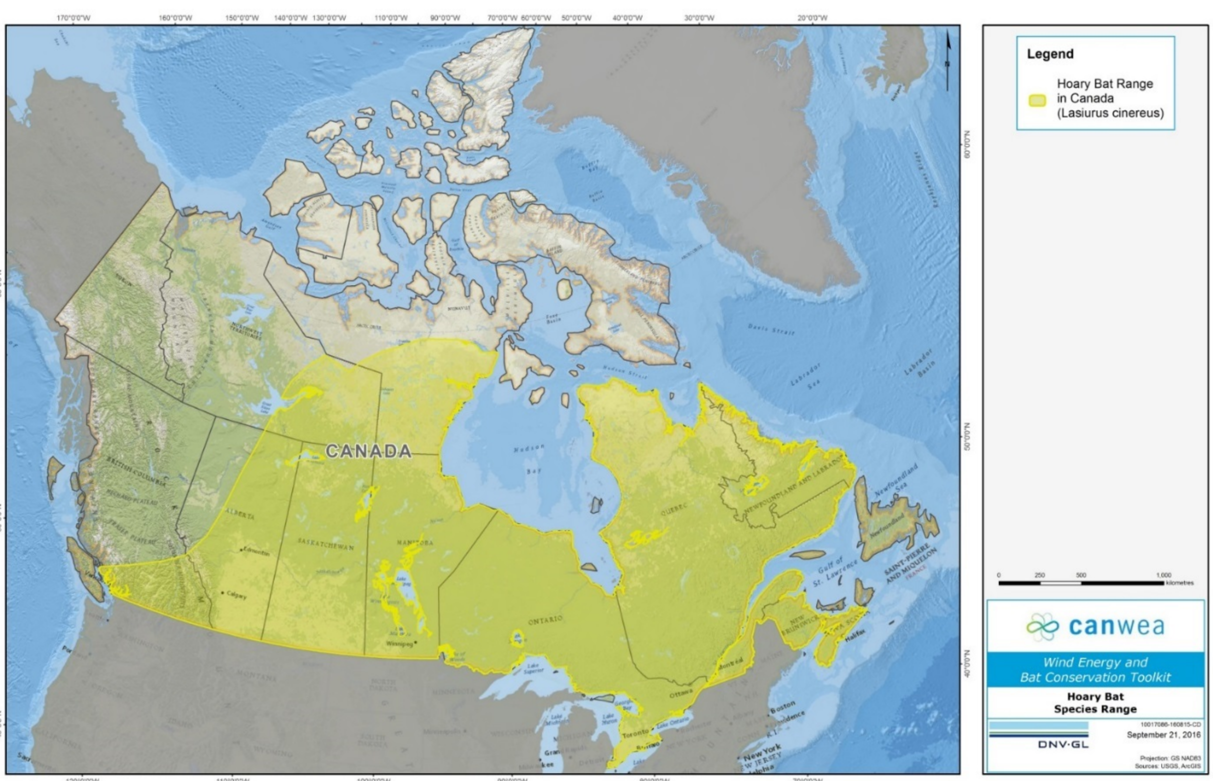
Key Identification Features

One of the largest Canadian bat species, hoary bat (*Lasiurus cinereus*) can be distinguished from other Canadian bat species by its size and fur colour [19]. Hoary bat has thick fur (including on the uropatagium) with a brown base and grey to white tips (frosted/hoary appearance), with a yellowish ruff of fur around the face [29]. They have fur in the corner of the wrist joint on the wing and their ears are rounded with black edges. Key identification features of hoary bats include [19], [29]:

- Uropatagium has fur;
- Ears round with black edges;
- Fur on body is brown, with grey to white tips;
- Yellowish ruff of fun around the face;
- Forearm length: 46 to 61 mm (mean = 54 mm);
- Body length: 99 to 143 mm;
- Ear length: 13 to 20 mm; and
- Wingspan: 34 to 41 cm.

Range

The hoary bat is among the most widespread of all bats, ranging throughout most of Canada (although limited range in British Columbia and the territories), United States (including Hawaii, where the hoary bat subspecies is the only wild land mammal to naturally colonize the islands), and Central and South America.



Population Numbers

Hoary bats are common and current population numbers are believed to be at or below 2.5 million [7]; however, more research is necessary to determine the exact population size of hoary bat [28].

Habitat Preferences

Hoary bats typically roost 3 to 5 m above the ground, up in the trees along forest edges or clearings [21]. Hoary bats appear to prefer evergreen trees as roosting habitats [27]. In Ontario, hoary bats tend to occur in forest stands with large live trees and relatively open canopies [231]. The species typically forages above the trees along streams and lake shores [28]. Swarming activity of hoary bat was also observed during a study of 17 abandoned mines and eight caves in Nova Scotia in late August and early September [289].

Foraging and Breeding Behaviour

Hoary bats are typically solitary roosters that remain well camouflaged in their roost [29]. Swarming activity of hoary bat was observed however during a study of 17 abandoned mines and eight caves in Nova Scotia [289].

Hoary bats typically forage after dark in the summer, however, during migration, they may emerge earlier after sunset [21]. They can make round trips of up to 39 km on the first foraging flight of the night, followed by several shorter trips, and returning to the roost about an hour before sunrise. They typically eat insects, particularly moths, but have also been found to eat grass, small snakes, and even other bats [29].

During migration, hoary bats travel in groups [21]. Late summer to early fall, they begin their migration south to spend the winter in sub-tropical and tropical areas.

Keen's Long-eared Bat (*Myotis keenii*)[10]

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	S2S3 (Imperiled to Vulnerable)	Identified Wildlife
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		Data Deficient	Special Concern
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

Keen's long-eared bat (*Myotis keenii*) has glossy, dark brown dorsal fur, indistinct dark shoulder spots, lighter brown ventral fur, and dark brown to black wings and ears [19], [49]. Keen's long-eared bat has large ears with a long, slender, pointed tragus [19]. Keen's long-eared bat is similar in appearance to long-eared myotis (*M. evotis*), and the two species cannot reliably be distinguished in the field [19]. It is debated whether Keen's long-eared bat is a distinct species or is a coastal subspecies of long-eared myotis [49]. Key identification features of Keen's long-eared bat include [19]:

- Ears are large and dark brown to black, with a long, slender, pointed tragus;
- Fur on body is dark brown on back, with lighter brown on abdomen;
- Forearm length: 34 to 40 mm;
- Body length: 63 to 94 mm;
- Ear length: 13 to 20 mm; and
- Wingspan: 22 to 26 cm.

Range

Confined to the North American Pacific coast, Keen's long-eared bat inhabits coastal forests of southeastern Alaska, western British Columbia (including Vancouver Island), and western Washington [19], [21], [49]. Keen's long-eared bat has one of the most restricted ranges of any North American bat, and as very few records of Keen's long-eared bat exist, the range is an approximation [19], [49].

[10] May be merged with the long-eared myotis (*Myotis evotis*) in the near future as there has been recent genetic evidence that shows the two species are a single species that interbreeds [372].

Population Numbers

No estimates of Keen's long-eared bat population size or trends are available [47], [48]. Keen's long-eared bat is uncommon throughout its range, and the lack of available records makes it difficult to determine population size or trends [19].

Habitat Preferences

Keen's long-eared bat prefers to inhabit old-growth rainforests [19], [21]. Keen's long-eared bat forages in rainforests in proximity to water, at heights ranging from near ground level to the canopy [19]. Keen's long-eared myotis has also been observed in estuaries, over rivers and lakes, and in urban settings [19]. The roost requirements of Keen's long-eared bat are not clearly understood, but it is thought to use hollow trees, snags, rock crevices, cliff faces, caves, bridges, and buildings [19]. Two maternity colonies have been discovered within British Columbia, one on the Queen Charlotte Islands and one on Vancouver Island; the only known Keen's long-eared bat hibernaculum is on Vancouver Island [19].

Foraging and Breeding Behaviour

Capable of slow flight speeds and maneuverability, Keen's long-eared bat is adapted to foraging in the dense vegetation of coastal rainforests [19]. Keen's long-eared bat gleans prey from vegetation, allowing it to hunt in cool temperatures or rain that may prevent insects from flying [19]. Keen's long-eared bat eats spiders and flying insects, but little else is known about its diet [19]. Keen's long-eared bat forages in several short bursts separated by roosting periods, leavings its roost 20 to 30 minutes after sunset and returning approximately two hours before sunrise [19].

Mating occurs in the fall, and young (one pup per reproductive female) are born in June or July [19], [49]. The one known Canadian maternity site is used from late May to mid-August [19].

Keen's long-eared bat hibernates singly or in small clusters [19]. Keen's long-eared bat appears not to undergo long-distance migrations, but seasonal shifts in habitat may occur [49].

Little Brown Myotis (*Myotis lucifugus*)

Range		***Conservation*** [1]	***Legal*** [2]
Provincial	AB	S5 (Secure)	-
	BC	S4 (Apparently Secure)	-
	MB	S2N, S5B (Imperiled-Nonbreeding, Secure-Breeding)	Endangered
	NB	S4 (Secure)	Endangered
	NL	S4 (Secure)	-
	NS	S4 (Secure)	Endangered
	NT	S2 (Imperiled)	-
	NU	SNR (Unranked)	-
	ON	S4 (Apparently Secure)	Endangered
	PE	Se (Secure)	Endangered
	QC	S1 (Critically Imperiled)	-
	SK	S5B, S5M (Secure-Breeding, Secure-Migrant)	-
	YT	S1S3 (Critically imperiled to vulnerable)	Endangered
Federal		Endangered	Endangered
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing per applicable provincial law; federal listing under SARA [44].

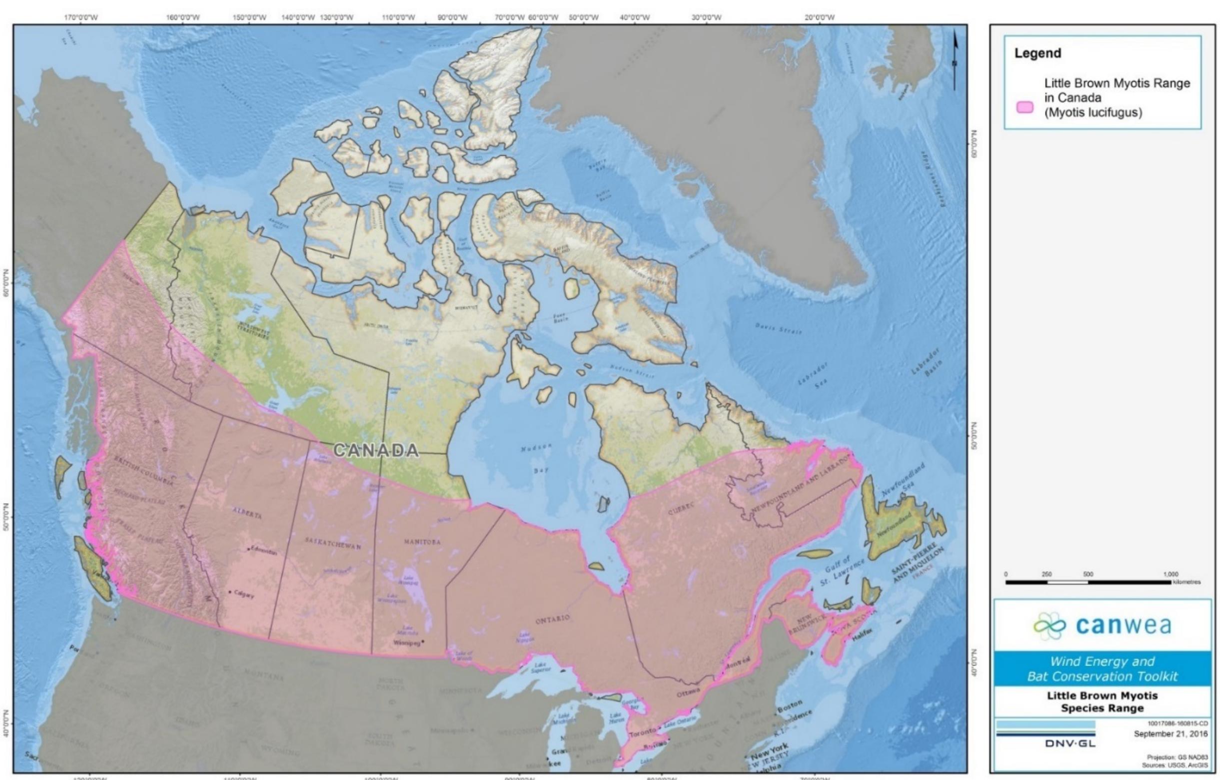
Key Identification Features

Adult little brown myotis (*Myotis lucifugus*) have glossy bi-coloured fur (darker at base) [29]. The fur colour is variable, including yellowish brown, olive brown, rusty brown, dark brown, and almost black with the abdomen often lighter [19]. The fur on the abdomen extends onto wing membranes and their uropatagium is lightly furred [19], [292]. The wings and ears of the little brown myotis are dark brown, and calcar is not keeled. Key identification features of little brown myotis include [19], [29]:

- Ears are short and dark brown, with a long, thin tragus rounded at the tip;
- Fur on body is bi-coloured, with darker colouration at the base;
- Forearm length: 33 to 41 mm (mean = 38 mm);
- Body length: 60 to 108 mm;
- Ear length: 12 to 16 mm; and
- Wingspan: 22 to 27 cm.

Range

Little brown myotis is found across Canada (except Nunavut) and the United States [21], [41]. In Canada, little brown myotis range from Labrador, and south of Hudson Bay and across central Canada [19]. The range of little brown myotis extends south to southern California, northern Arizona, and New Mexico [21]. Little brown myotis also exists in Mexico in limited abundance [19], [292], [293].



Population Numbers

The Canadian population size is unknown, but likely consisted of more than one million individuals before the arrival of white-nose syndrome [53]. Eastern Canadian subpopulations of little brown myotis are rapidly declining due to white-nose syndrome; there has been an estimated 94% overall decline in numbers [53]. Recently, white-nose syndrome was confirmed in a little brown myotis individual found near North Bend, Washington [11]. This occurrence of white-nose syndrome is 1,300 miles west of the previously known westernmost detection of white-nose syndrome in North America, lending to the potential for this disease to spread west in Canada as well.

Habitat Preferences

Little brown myotis roost in a variety of small spaces including rock crevices, hollow trees, houses, and barns [29]. Preference is given to roosts in close proximity to water and other foraging sites [21]. Little brown myotis roosts in groups from a few individuals to several thousand [29], [293]. During the winter months, the little brown myotis hibernates in high humidity caves and abandoned mines [29]. The bat requires hibernacula which maintain temperatures above freezing during the winter [29].

Foraging and Breeding Behaviour

Little brown myotis forage over water, feeding on a variety of small insects [29]. They also forage in farmland, meadows, cliff faces, and forested trails, on insects including moths, beetles and crane flies [21]. They often forage between 1 to 6 m above ground or at water level [19], [292]. Foraging typically occurs 2 to 3 times per night for approximately 15 minutes each time [19], [293].

Little brown myotis mate at swarming sites during late summer and early autumn, with females giving birth to a single pup in June of the following year [19], [29]. Little brown myotis is the best studied species with respect to hibernacula use in Canada. It has been observed swarming (i.e. nocturnal flights through hibernacula) at 10 abandoned mines/caves in Ontario and Quebec. At one swarming site the species comprised over 90% of the bats captured, with juveniles comprising over 50% of the swarming population [294]. Swarming activity of little brown myotis was also observed during a study of 17 abandoned mines and eight caves in Nova Scotia in late August and early September [289]. Swarming by the little brown myotis generally occurs in two phases in August and September [294]. Females raise pups in maternity colonies which need to maintain temperatures between 32 to 36 °C [19]. Some females in the southern portion of the range are sexually mature during their first autumn (post-natal) and can successfully mate [19].

Long-eared Myotis (*Myotis evotis*)

Range		***Conservation[1]***	***Legal[2]***
Provincial	AB	S3S4 (Vulnerable to Apparently Secure)	-
	BC	S4S5 (Apparently Secure to Secure)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	S2 (Imperiled)	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	S3B, SNRN (Vulnerable – Breeding, Unranked – Nonbreeding)	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

Long-eared myotis (*Myotis evotis*) is a medium-sized bat with long, dark ears that extend > 5 mm beyond the nose when pressed forward [19], [21]. Long-eared myotis has pale brown or straw coloured fur that is long and soft [19], [295]. The uropatagium of long-eared myotis lacks hair [295]. The calcar of long-eared myotis is typically not keeled, but some individuals possess a slightly keeled calcar [19]. Key identification features of long-eared myotis include [19]:

- Ears are long and dark, extending > 5 mm beyond the nose when pressed forward;
- Fur on body is long and pale brown or straw coloured;
- Forearm length: 36 to 41 mm;
- Body length: 80 to 113 mm;
- Ear length: 18 to 22 mm; and
- Wingspan: 25 to 29 cm.

Range

Long-eared myotis is found in western Canada, United States, and Mexico [19], [50]. Within Canada, long-eared myotis is found in southern British Columbia, Alberta, and Saskatchewan [50]. Long-eared myotis is considered uncommon through its range [19], [295].

Population Numbers

Long-eared myotis has stable populations [50].

Habitat Preferences

Long-eared myotis prefers coniferous forests and is typically found at elevations from 2,000 to 2,500 m [19], [21]. Long-eared myotis commonly roosts in tree cavities and bark crevices [19]. Pregnant females roost at ground level under rocks, in stumps, and in fallen logs [19]. Males and non-reproductive females often roost alone, while pregnant females frequently roost in small groups of up to 30 individuals [19].

Limited data is available on long-eared myotis hibernacula; however, it is assumed that long-eared myotis travels short distances between summer and winter roosts [295].

Foraging and Breeding Behaviour

Long-eared myotis forages near water and can also forage within tree canopies due to its relatively quiet echolocation calls [19], [295]. The quiet calls and ability to glean allow long-eared myotis to easily capture moths [19]. Males forage twice nightly, around 30 minutes after sunset and a few hours prior to sunrise [19]. Females forage for the majority of the night and switch between aerial hawking and gleaning throughout the night [19].

Long-eared myotis breeds in late autumn and early winter, and the female gives birth to a single pup the following June or July [19]. By their first autumn, juveniles are essentially indistinguishable from adults [19].

Long-legged Myotis (*Myotis volans*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	SU (Unrankable)	-
	BC	S4S5 (Apparently Secure to Secure)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	S2 (Imperiled)	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

Long-legged myotis (*Myotis volans*) varies in colour from reddish brown to almost black, with darker individuals found in coastal regions [19]. Long-legged myotis has short rounded ears, and its ears and wings are blackish brown [19]. Long-legged myotis can be distinguished by its long, keeled calcar and the thick fur which extends onto the underside of its wings to the elbow and knee [52]. The dorsal side of the long-legged myotis' uropatagium is also slightly furred [19]. Long-legged myotis has a longer tibia than other *Myotis* species; the tibia typically measures more than 19 mm from knee to heel [19]. Key identification features of long-legged myotis include [19]:

- Uropatagium is slightly furred;
- Ears are short, round and blackish brown in colour;
- Fur on body is reddish brown to almost black;
- Forearm length: 36 to 44 mm;
- Body length: 83 to 105 mm;
- Ear length: 9 to 16 mm; and
- Wingspan: 25 to 27 cm.

Range

Long-legged myotis is widely distributed throughout western North America, ranging from southeastern Alaska throughout western Canada and the United States to central Mexico [19], [21].

Population Numbers

Long-legged myotis can be found in colonies of 2,000 to 5,000 individuals throughout much of its range [51]. The range-wide population trend is stable [51].

Habitat Preferences

Long-legged myotis prefers wooded habitats, and can be found in montane and coastal coniferous forests, as well as in arid habitats [19], [21]. In the United States, long-legged myotis is known to roost in buildings, rock crevices, and trees [52]. Long-legged myotis maternity colonies are often found in mature trees (beneath bark or in other tree cavities), and are also found in rock crevices, cliffs, and buildings [21], [52]. Long-legged myotis forages over water and clearings, along cliff faces, and within and above forest canopies [19]. It is not known where many of these bats hibernate [52]. Long-legged myotis are generally associated with contiguous forests with limited openings, and have been found to associate with old-growth Douglas-fir (*Pseudotsuga menziesii*) [296]. There is evidence that this association is driven by use of the forests for foraging or commuting, but not as roosting habitat [297].

Foraging and Breeding Behaviour

Long-legged myotis emerges from its day roost at dusk [19]. An opportunistic forager, long-legged myotis eats whatever flying insects are available; it prefer moths, but will consume termites, spiders, flies, beetles, leafhoppers, and lacewings [19]. Long-legged myotis is a cold-tolerant species, often hunting in cooler temperatures than other bats [19], [52].

Long-legged myotis mates in the fall, and in Canada young are born in late June and July [19]. Maternity colonies often consist of hundreds of individuals [52].

Northern Myotis (*Myotis septentrionalis*)

Range		***Conservation[1]***	***Legal[2]***
Provincial	AB	S2S3 (Imperiled to Vulnerable)	Data Deficient
	BC	S2S4 (Imperiled to Apparently Secure)	-
	MB	S3S4N, S4B (Vulnerable to Apparently Secure – Nonbreeding, Apparently Secure – Breeding)	Endangered
	NB	S4 (Apparently Secure)	Endangered
	NL	Newfoundland Island: S2S3 (Imperiled to Vulnerable); Labrador: SNR (Unranked)	-
	NS	S2 (Imperiled)	Endangered
	NT	S2 (Imperiled)	-
	NU	-	-
	ON	S3 (Vulnerable)	Endangered
	PE	S1S2 (Critically Imperiled to Imperiled)	Endangered
	QC	S1 (Critically Imperiled)	-
	SK	S4B, SNRN (Apparently Secure – Breeding, Unranked – Nonbreeding)	-
	YT	S1S2 (Critically Imperiled to Imperiled)	Endangered
Federal		Endangered	Endangered
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

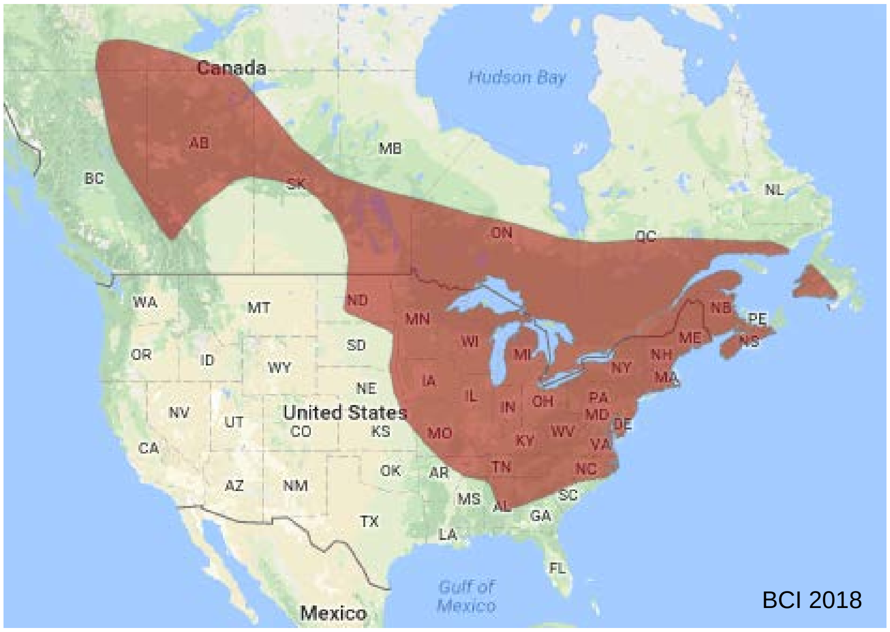
Key Identification Features

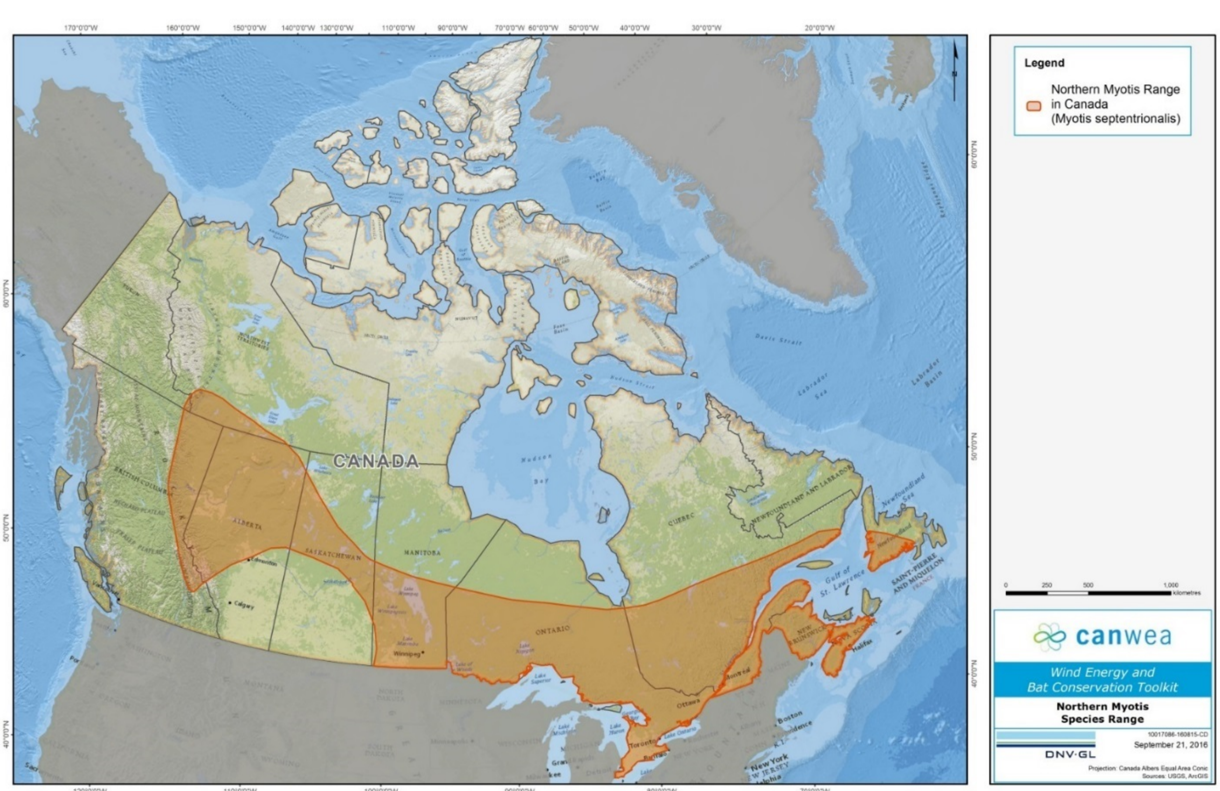
A small bat, northern myotis (*Myotis septentrionalis*) is similar in colouring and size to little brown myotis [53]. Northern myotis has glossy light to medium brown fur with darker brown ears, snout, and wings [19], [29]. Northern myotis can be distinguished from little brown myotis by its long, slender tragus with a sharp, pointed tip, as well as by its moderately long ears [19], [29], [53]. Northern myotis also has a moderately long tail and slightly keeled calcar [19]. Key identification features of northern myotis include [19], [29]:

- Ears are brown and moderately long, with long, slender tragus with a sharp, pointed tip;
- Fur on body is light to medium brown;
- Forearm length: 33 to 39 mm (mean = 36 mm);
- Body length: 77 to 101 mm;
- Ear length: 14 to 19 mm; and
- Wingspan: 22 to 26 cm.

Range

Northern myotis is commonly found in eastern Canada, including Prince Edward Island, and in the eastern United States [19]. Northern myotis is found across Canada to British Columbia, but populations become patchy in the western portion (west of Ontario) of the range [19], [298].





Population Numbers

The Canadian population size is unknown, but likely consisted of more than one million mature individuals before the arrival of white-nose syndrome [53]. Eastern Canadian subpopulations of northern myotis are rapidly declining due to white-nose syndrome; there has been a 94% overall decline in numbers of eastern Canadian subpopulations since 2010 [53].

Habitat Preferences

Northern myotis roost under bark and in crevices, houses, and barns [29]. Northern myotis has also been observed roosting in trees with low levels of canopy cover, although this is uncommon [298]. Northern myotis roosts are located within 1km of optimal foraging areas [19]. Swarming activity of northern myotis was observed during a study of 17 abandoned mines and eight caves in Nova Scotia in late August and early September [289].

Northern myotis have been observed to travel up to 56 km when moving from winter to summer roost locations [19]. Over winter, the species hibernates in caves and abandoned mines, often alone or in small clusters, and often with colonies of other bat species [19], [29], [298]. Northern myotis hibernate from approximately October or November until March or April [41].

Foraging and Breeding Behaviour

Northern myotis forage using both aerial hawking and gleaning, leading to their ability to feed on a wide variety of flying and non-flying prey [29]. Northern myotis can forage on larger prey than other small bats since it brings its prey to a perch before consuming it [19]. Northern myotis forage in cluttered areas since they have the ability to adjust their echolocation frequency [19]. Northern myotis typically forages over a 65 ha area, beginning within the first two hours following sunset and a few hours prior to sunrise [19].

Northern myotis mate during late summer and autumn at swarming sites [29]. Females give birth to a single pup the following June [29]. The juveniles are indistinguishable from adults during the first autumn [19].

Pallid Bat (*Antrozous pallidus*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	S2 (Imperiled)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		Threatened	Threatened
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

The pallid bat (*Antrozous pallidus*), one of Canada's largest bat species, is light yellowish-brown in colour with a pale abdomen [55]. Pallid bat has short fur, dark grey wings, and large tan-coloured ears [19]. Males and females are similar in appearance, although females are slightly larger [19]. Key identification features of pallid bat include [19]:

- Ears are large and tan-coloured;
- Fur on body is yellowish-brown, with a pale abdomen;
- Forearm length: 48 to 57 mm;
- Body length: 102 to 135 mm;
- Ear length: 26 to 33 mm; and
- Wingspan: 31 to 37 cm.

Range

The pallid bat is a western North American species, found in western Canada, western United States, Mexico, and Cuba [19]. In Canada, pallid bat occurs only in the Okanagan Valley of south-central British Columbia, which is the northern limit of its distribution [19], [55]. The range of the pallid bat in Canada is estimated to consist of no more than 500 km^2 [55].

Population Numbers

Although abundant in the south-western United States, pallid bat is rare in Canada [55]. The Canadian population size of pallid bats is unknown, but is estimated to consist of at least 250 and less than 1,000 mature individuals [19], [54].

Habitat Preferences

As a desert-adapted species, the pallid bat inhabits arid and semi-arid regions of western North America [19], [55]. Pallid bat can be found in habitats including deserts, dry grasslands, sagebrush, and cultivated fields, often near rocky outcrops and water [19], [57]. It may also inhabit coniferous forests and woodlands [19], [57]. In British Columbia, the pallid bat is restricted to valley bottoms at low elevations, and forages in open, sparsely vegetated regions [19], [55], [56].

Pallid bat requirements for breeding and day roost habitats are very similar [55]. The pallid bat generally roosts in crevices of rock outcrops, steep cliffs, canyon walls, and talus slopes [19], [57]. It is also known to roost in buildings, caves, abandoned mines, stone piles, and tree cavities [55], [57]. The pallid bat shifts its day and night roosts fairly frequently [19].

The pallid bat hibernates in caves and abandoned mines, but no winter hibernacula have been observed in British Columbia [19], [56].

Foraging and Breeding Behaviour

The pallid bat typically forages in areas nearby its day roost [57]. Pallid bat emerges from its day roost relatively late in the day, and often undertakes two foraging periods separated by a night roosting interval [19], [57]. The pallid bat primarily preys on beetles and moths, gleaning its prey from the ground or vegetation [55], [57]. In the United States, it is known to feed on large insects, spiders, scorpions, lizards, small rodents, and potentially smaller bats [19]. The pallid bat often brings large prey items back to its night roost [19].

Little is known about the reproduction of pallid bat in British Columbia [56]. Maternity colonies are generally small, but may consist of over 200 adults [19], [57]. The pallid bat mates from October to December, and most young are born over a two-week period in May or June (likely late June in the northern extent of the range) [19], [57]. Young are able to fly at an age of 5 to 6 weeks [19], [57].

Silver-haired Bat (*Lasionycteris noctivagans*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	S3 (Vulnerable)	-
	BC	S4S5 (Apparently Secure to Secure)	-
	MB	S3S4B (Vulnerable to Apparently Secure – Breeding)	-
	NB	S1? (Critically Imperiled – Inexact or Uncertain)	-
	NL	-	-
	NS	S1? (Critically Imperiled – Inexact or Uncertain)	-
	NT	SU (Unrankable)	-
	NU	-	-
	ON	S4 (Apparently Secure)	-
	PE	-	-
	QC	S3 (Vulnerable) / Likely To Be Designated	-
	SK	S5B, S4M (Secure – Breeding, Apparently Secure – Migrant)	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

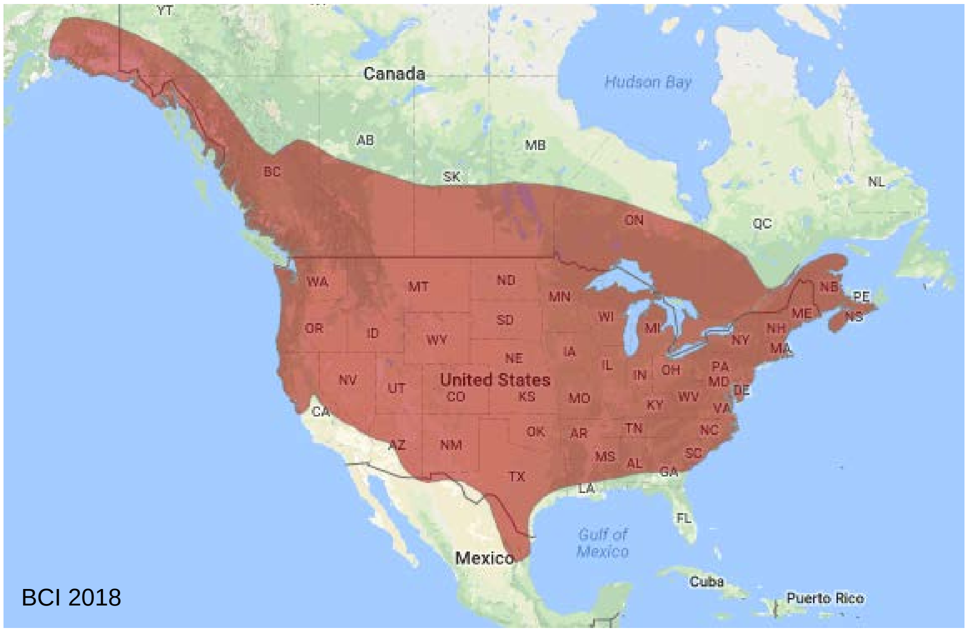
Key Identification Features

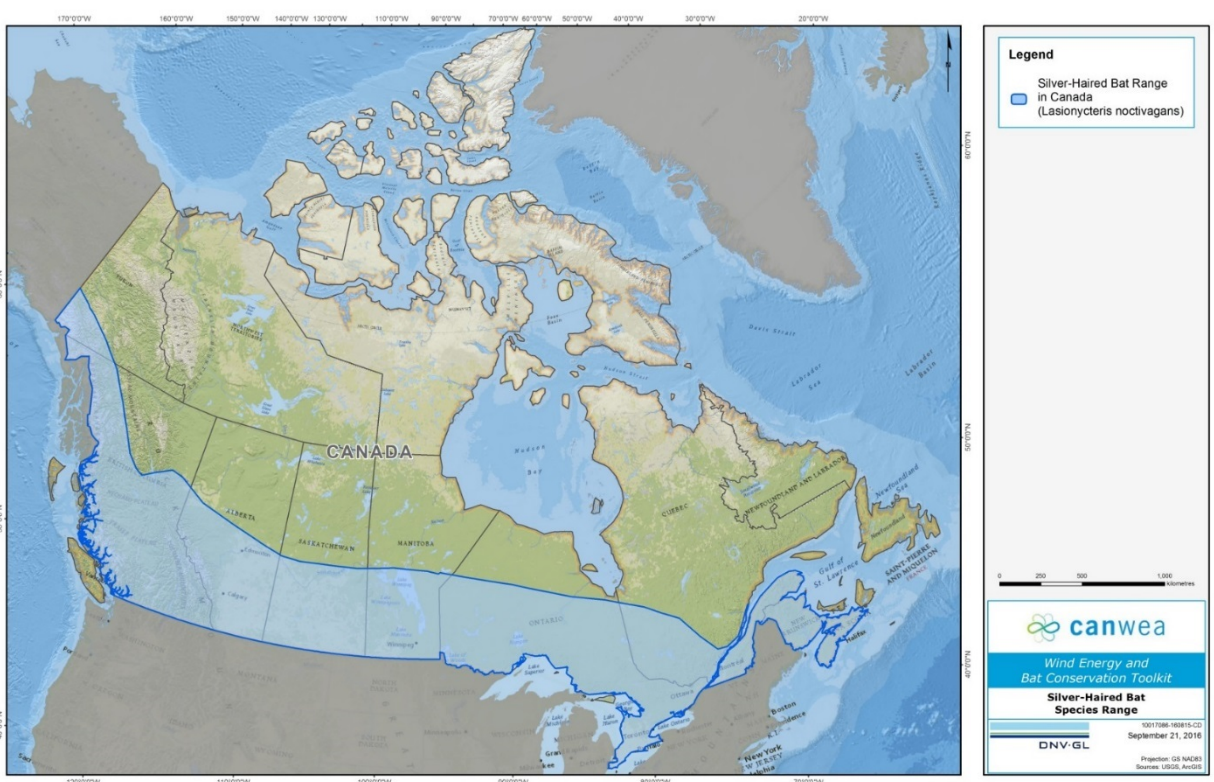
The silver-haired bat (*Lasionycteris noctivagans*) has black flight membranes, ears, and fur (including on the uropatagium) [19]. Individual hairs on the dorsal and ventral sides are tipped with white, giving the silver-haired bat a frosted appearance [19], [29]. These identification features serve to distinguish this bat from any other Canadian bat species [19]. Key identification features of silver-haired bats include [19], [29]:

- Uropatagium has fur;
- Ears are short, round entirely hairless;
- Fur on body is black, with white tips;
- Forearm length: 36 to 44 mm (mean = 41 mm);
- Body length: 80 to 113 mm;
- Ear length: 10 to 18 mm; and
- Wingspan: 27 to 31 cm.

Range

Silver-haired bats are found throughout most of the central North America. In Canada, Silver-haired bats are found across all provinces, with the exception of those in the far east (i.e., Prince Edward Island and Newfoundland). Southward they also extend into Mexico [30]. The silver-haired bat is migratory, so most of the northern portion of its range is not occupied in winter and most of the southern range is not occupied in the spring and summer [19].





Population Numbers

Population numbers for the silver-haired bat are unknown [30]. Within Canada, it is considered common to rare, depending on the season and the region. The population density is considered highly variable from year to year and is most likely dependent on temperature and the effect it has on reproduction [19].

Habitat Preferences

Silver-haired bats are highly adaptable to diverse habitats but prefer temperate, northern hardwoods with ponds or streams nearby. Old-growth forests are also a preference and silver-haired bats are particularly fond of willow, maple, and ash trees (most likely due to the deeply fissured bark) [19], [30]. It is estimated that silver-haired bats require snag densities of at least 21 per hectare [30]. Silver-haired bats depend on old-growth forest areas for roosting, but feed predominantly in disturbed areas, at tree-top level or in small clearings and along roadways or water courses [30]. In some cases the species has demonstrated a negative response to area of contiguous forest, and appears to prefer small forested patches with high stem densities interspersed with open areas [288].

Summer roost sites and maternity roosts are typically found in tree cavities or under loose bark [19], [30]. Swarming activity of silver-haired bat was also observed during a study of 17 abandoned mines and eight caves in Nova Scotia in late August and early September [289]. Silver-haired bat typically hibernates in similar habitats, under loose bark or within tree cavities, although they migrate southwards to do so [30].

Foraging and Breeding Behaviour

Silver-haired bats typically emerge shortly after sunset to forage for small insects and they have two foraging cycles per night [19]. Silver-haired bat is a generalist, known to eat a variety of small to medium sized insects [31]. They primarily feed during flight, but have been observed consuming larvae on trees and occasionally will go to the ground [30].

Mating for silver-haired bat happens in the fall, potentially during migration, and females store the sperm until the following year [19]. Females typically give birth to 2 pups within a maternity colony in a tree hollow [19].

During migration, which occurs at night, silver-haired bats travel in small groups or individually [19].

Spotted Bat (*Euderma maculatum*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	S3S4 (Vulnerable to Apparently Secure)	Identified Wildlife
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		Special Concern	Special Concern
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

A medium-sized species, the spotted bat (*Euderma maculatum*) has long black dorsal fur and is named for the three large white spots on its back (one on each shoulder and a larger spot on the rump) [19], [44]. Spotted bat has white ventral fur, and also has small white patches of fur behind its ears [19]. The spotted bat has very large, pinkish-grey ears, which are joined at the base across its forehead [19], [44]. The spotted bat will furl its ears over its back except when in flight. Its wings are pinkish-red in colour. Key identification features of spotted bat include [19]:

- Ears are very large, joined at the base across forehead, and pinkish-grey in colouration;
- Fur on body is long and black with white spots on back, and white on abdomen;
- Three large white spots on back;
- Forearm length: 48 to 53 mm;
- Body length: 107 to 125 mm;
- Ear length: 34 to 41 mm; and
- Wingspan: 34 to 35 cm.

Range

Information regarding spotted bat range is not well known and the distribution within the known range may be patchy [299]. Within Canada, the spotted bat is found only within the arid regions of south-central British Columbia, including the interior valleys of the Okanagan, Similkameen, Thompson, Fraser, and Chilcotin Rivers. The overall range extends from southern British Columbia throughout the western United States to central Mexico [19].

Population Numbers

Within British Columbia, the current population estimates for the spotted bat is less than 1,000 individuals [19]. As spotted bat is rare with localized and patchy populations, it is possible that other populations have yet to be found. Spotted bat is also relatively solitary with individuals being well dispersed and often separated by 750 to 1,000 m [299].

Habitat Preferences

The spotted bat occurs in various habitat types, including dry forested areas, grasslands, canyon bottoms, riparian and river corridors, meadows, and open pastures [58]. In British Columbia, spotted bat occupies grassland and open coniferous forests within dry river valleys [19]. The spotted bat prefers roosting habitats, including maternity roosts, of rock crevices and cracks in cliffs and sometimes within caves or in buildings near cliffs [19], [58].

In British Columbia, foraging occurs primarily in fields near pine trees and over marshes [59].

Winter habitat for the spotted bat is poorly known [58].

Foraging and Breeding Behaviour

The spotted bat emerges from its roost to forage in complete darkness and it will generally forage within 10 km of the roost site (but has been known to travel more than 35 km within the United States) [19]. Individuals within British Columbia use the same roost each night from May to July, but not after early August [59]. While foraging, spotted bats travel at approximately 20 km/hr in large elliptical patterns and fly 5 to 15 m above the ground [19], [58]. Individuals establish a foraging path that they will follow for several days, visiting the same place at the same time. They will also hunt while commuting and most individuals will fly continuously from the time they leave the day roost until they return [19].

Moths are the primary food source for spotted bats, although a small percentage of their diet is other insects [58].

Limited information is known regarding the breeding behaviour of the spotted bat. Spotted bats do not appear to form nursery colonies [19].

Townsend's Big-eared Bat (*Corynorhinus townsendii*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	S3 (Vulnerable)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

Townsend's big-eared bat (*Corynorhinus townsendii*) is a medium-sized species, characterized by very large ears, which are joined at the base across the forehead [300]. The tragus is around one-third of the length of the ear and is pointed [19], [301]. Townsend's big-eared bat has two large glandular swellings on either side of its snout, and its calcar is not keeled [19], [300]. Townsend's big-eared bat has long dorsal fur, which is grey with pale to dark brown tips, and the ventral fur is slightly lighter [19], [300]. There is a darker form found along the west coast and a lighter form found inland [19]. Key identification features of Townsend's big-eared bats include [19]:

- Ears are very large, joined at the base across forehead, with pointed tragus (1/3 ear length);
- Fur on body is grey, with pale to dark brown tips;
- Forearm length: 39 to 45 mm;
- Body length: 83 to 113 mm;
- Ear length: 27 to 40 mm; and
- Wingspan: 23 to 31 cm.

Range

Townsend's big-eared bat is widely distributed across western North America, from southern British Columbia to southern Mexico [19], [300]. There are also several isolated populations in the eastern United States [19], [300]. In Canada, Townsend's big-eared bat is at the northern limit of its distribution and only inhabits south-central British Columbia and southern Vancouver Island [19].

Population Numbers

The population numbers within Canada are unknown and Townsend's big-eared bat is presumed rare as the extent of distribution is poorly known [19]. Within its global distribution, the Townsend's big-eared bat is presumed to have a large population, although the numbers are unknown [60].

Habitat Preferences

Townsend's big-eared bats have versatile habitat preferences that range from humid coastal forests, arid scrublands, open dry forests, grasslands, coniferous forests and woodlands, and deciduous riparian woodlands, although they prefer roosting in caves and abandoned mines [19], [60]. Townsend's big-eared bat will also utilize old buildings, bridges, culverts, and large hollow trees in the summer and prefers open roost areas that allow them to fly to their roosting spot (i.e., not cracks or crevices) [19]. They forage over wetlands, forest edges, and open woodlands [19].

Foraging and Breeding Behaviour

Townsend's big-eared bats are agile fliers, capable of slow flight and occasional hovering [19]. They emerge to hunt once fully dark and typically forage within a couple kilometers of their day roost [19]. Their food preference is moths (3 to 10 mm in size), but Townsend's big-eared bat will also forage on other flying insects, including beetles, flies, lacewings, and sawflies [19], [60]. Townsend's big-eared bats generally forage near vegetation surfaces in the sub-canopy or close to the ground [19].

Townsend's big-eared bat usually has two mating phases, one in the summer and one in the winter [21]. In British Columbia, most young are born from mid-June to mid-July [19]. In the summer months, females form a nesting colony (one or more small clusters of less than 100 bats) while males are typically solitary during the maternity periods [60].

Townsend's big-eared bat hibernates within Canada from mid-September to the end of May [19]. They hibernate either individually or in groups composed of several hundred bats [60].

Tri-colored Bat (*Perimyotis subflavus*)

Range		***Conservation*** [1]	***Legal*** [2]
Provincial	AB	-	-
	BC	-	-
	MB	-	-
	NB	S2? (Imperiled – Inexact or Uncertain)	Endangered
	NL	-	-
	NS	S1? (Critically Imperiled – Inexact or Uncertain)	Endangered
	NT	-	-
	NU	-	-
	ON	S3? (Vulnerable – Inexact or Uncertain)	Endangered
	PE	-	-
	QC	S1 (Critically Imperiled) / Likely To Be Designated	-
	SK	-	-
	YT	-	-
Federal		Endangered	Endangered
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

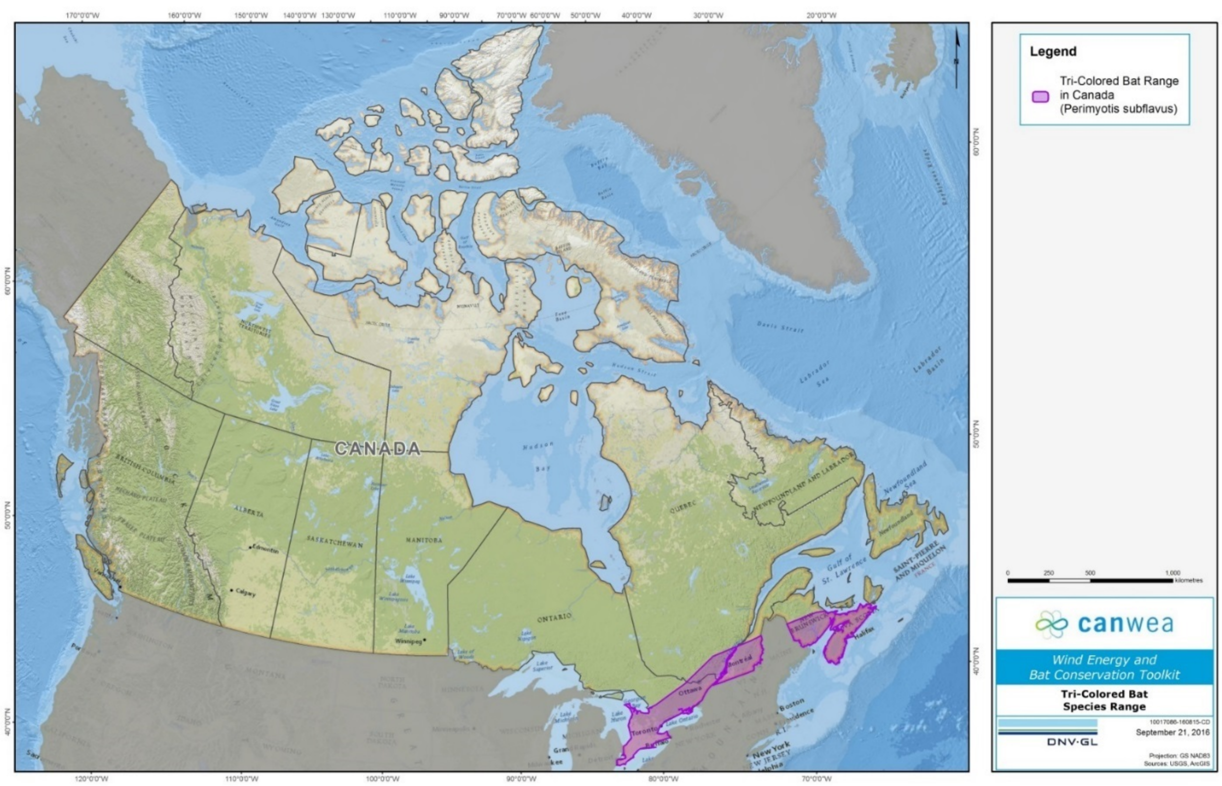
Key Identification Features

The tri-colored bat (*Perimyotis subflavus*), formerly eastern pipistrelle (*Pipistrellus subflavus*), is distinguished by its long, 3-coloured hair (dark at the base and tip, lighter in the middle) [19]. Tri-colored bat general colouration is yellowish to reddish brown, with lighter fur on the underside [19]. Tri-colored bat has a brown face, black flight membranes, and pink skin over the forearm and wing bones [19]. The ears are brown, slightly longer than its snout (when pressed forward), and have a tragus that is short, tapered, and rounded at the tip [19]. Key identification features of tri-colored bats include [19], [29]:

- Ears are slightly long and brown, with a short, tapered tragus rounded at the tip;
- Fur on body is 3-coloured, with dark at the base and tip and lighter in the middle;
- Forearm length: 33 to 37 mm (mean = 35 mm);
- Body length: 74 to 98 mm;
- Ear length: 11 to 15 mm; and
- Wingspan: 20 to 26 cm.

Range

The tri-colored bat's range extends from the Maritimes to the Great Lakes, and south to the east coast of Central America; the range may be expanding further west [53]. The Canadian portion of the range of the tri-colored bat, which extends through southern Nova Scotia, New Brunswick, Quebec, and Ontario accounts for only 10 to 15% of its global range [53].



Population Numbers

The tri-colored bat was formerly one of the most common species in eastern forests [21]. Currently, the Canadian population size is unknown; however, eastern Canadian subpopulations of tri-colored bat are rapidly declining [53]. There has been a 94% overall decline in numbers in eastern Canadian subpopulations since 2010 [123].

Habitat Preferences

Little is known about tri-colored bat summer daytime and maternity roosting habitats, but they appear to prefer roosting in tree foliage and clumps of lichen, caves and crevices, and rarely barns and other buildings [21], [61]. In Canada, the species has been shown to respond negatively to increasing area of contiguous forest and may prefer more fragmented landscapes [288]. They are short-distance migrants that overwinter in caves and abandoned mines, with a specific need for deeper caves with higher humidity and temperatures that are warmer and more stable [53]. Although they are usually found with *Myotis* species (in much smaller numbers), they prefer warmer temperatures than most bats, hibernate even where winters are warmer, and are usually the first to enter hibernation and the last to leave [21], [61]. Swarming activity of tri-colored bat was observed during a study of 17 abandoned mines and eight caves in Nova Scotia in late August and early September [289].

Foraging and Breeding Behaviour

Tri-colored bats have small foraging ranges which are mainly over still water and along rivers, but will also forage along forest edges and in gaps in the forests [53]. They primarily eat flying beetles, flies, moths, and leafhoppers. They benefit agriculture by eating pests that hatch from corn, and can easily eat half their body weight per night in insects [19], [21].

Tri-colored bat has a strong maternal philopatry, returning to the same trees in which they were born. Tri-colored bats mate in autumn while swarming cave entrances, and store sperm until they ovulate in the spring [53], [61]. Tri-colored bats have 1 to 2 pups that are born in July, which can weigh more than half of the female's normal weight, and are independent at four weeks [19].

Western Red Bat (*Lasiurus blossevillii*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	-	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		-	-
Global		-	-

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

The western red bat (*Lasiurus blossevillii*) has dense, shaggy fur that ranges in colour from orange to rusty red and is tipped with white [32], [33]. Western red bat has thick fur on the upper surface of its tail and hind feet [32]. The western red bat can be distinguished from other Canadian bat species by its colour, with the exception of eastern red bad (*Lasiurus borealis*), which has a frosted appearance and is larger [35]. Key identification features of western red bats include [32], [33], [35]:

- Uropatagium has fur;
- Fur on body is orange to rusty red in colouration, with white tips;
- White throat patch;
- Forearm length: 40 mm;
- Body length: 110 mm;
- Ear length: 10 to 15 mm; and
- Wingspan: 28 to 32 cm.

Range

The western red bat is found primarily in the western half of the United States, within Mexico and most of Central America [33]. Within Canada, western red bat may be found within the southern edge of Alberta and British Columbia, although no records have been found within Alberta and the records from British Columbia (Skagit Valley and Okanagan Valley) are questionable [21], [32]. Naughton indicated that the Canadian findings of what was thought to be western red bats have been determined to be eastern red bats through DNA testing [19].

Population Numbers

Population numbers for the western red bat are unknown and even though it has a wide distribution, there are few records for western red bat outside of California [34]. In Canada, if the western red bat is present, the number of individuals is believed to be quite low [32].

Habitat Preferences

The western red bat is a solitary tree-roosting bat and is closely associated with well-developed riparian habitats, especially cottonwoods, walnuts, oaks, willows, and sycamores (broad-leaved trees) at elevations below 6,500 feet [21], [33], [34]. Roost location preferences include areas where the leaves form a dense canopy above and branches below do not obstruct their flight paths. Within California western red bat is also known to roost in orchards [21].

Limited information is known about their migration, although it is believed they migrate to the southern part of their range to hibernate [33].

Foraging and Breeding Behaviour

The western red bat typically feeds along forest edges, in small clearings, or around street lights [21]. They generally begin to forage one to two hours after sunset and have two periods of foraging each night [35]. Western red bat is insectivorous and medium to large moths are the main prey item, but they will also eat beetles and grasshoppers [32]. Similar to its eastern counterpart, the western red bat uses its tail membrane to catch its prey [32].

There is limited information regarding the breeding habits of western red bat, especially within the northern extent of its range [32]. It is believed that the females give birth in June or early July and can have up to four pups, although three is the average [34], [35].

Western Small-footed Myotis (*Myotis ciliolabrum*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	S2 (Imperiled)	Special Concern
	BC	S2S3 (Imperiled to Vulnerable)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	S3B, SNRN (Vulnerable – Breeding, Unranked – Nonbreeding)	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

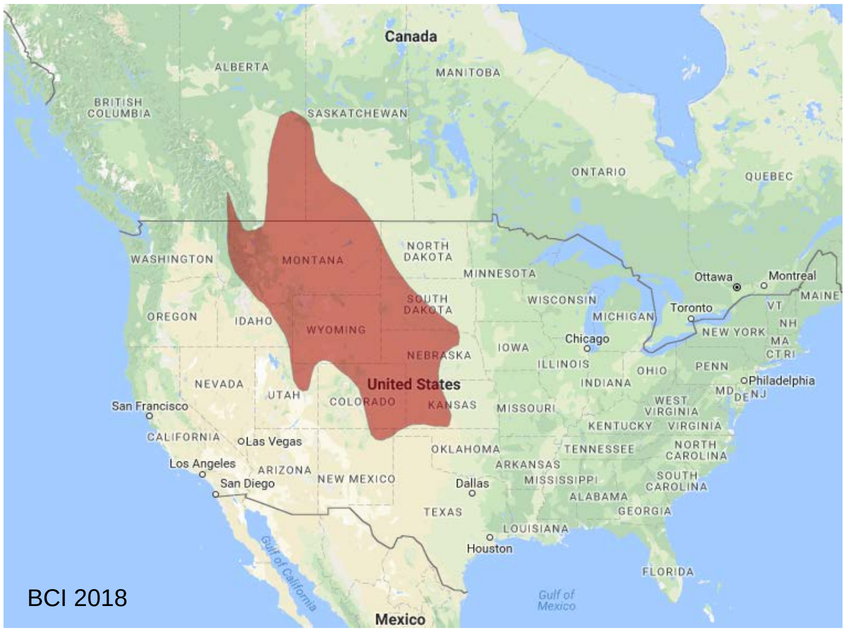
Key Identification Features

The smallest of the western Canadian bat species, western small-footed myotis (*Myotis ciliolabrum*) has pale yellow-brown to orange-brown dorsal fur, a paler abdomen, and black wings, ears, face, and snout [19]. Western small-footed myotis has a distinctly keeled calcar [19]. Key identification features of western small-footed myotis include [19]:

- Ears are black;
- Fur on body is pale yellow-brown to orange-brown, with a paler abdomen;
- Forearm length: 30 to 33 mm;
- Body length: 76 to 91 mm;
- Ear length: 13 to 17 mm; and
- Wingspan: 21 to 25 cm.

Range

Western small-footed myotis is found throughout western North America, from southern British Columbia to mid- and southern/central Alberta and Saskatchewan through the western United States to central Mexico [64], [302]. Western small-footed myotis does not occur in wetter coastal regions [19].



Population Numbers

The population size and trends of western small-footed myotis in British Columbia, Alberta, and Saskatchewan are unknown due to a lack of available data [62], [63].

Habitat Preferences

Western small-footed myotis inhabits arid and semi-arid habitats with cliffs, talus slopes, or clay banks, such as badlands, dry grasslands, and river valleys [63]–[65]. Western small-footed myotis is known to roost in rock crevices, caves, tunnels, under boulders and loose bark, and in buildings [19]. Maternity roosts are formed in abandoned houses or barns, caves, and crevices in rock faces or clay banks, and western small-footed myotis hibernates in caves and abandoned mines [64], [302]. Western small-footed myotis forages along cliffs and rocky slopes, over open water, and around cottonwood trees at heights between one meter and treetop level [19], [64], [65].

Foraging and Breeding Behaviour

Western small-footed myotis emerges from its daytime roost shortly after sunset to forage [19], [64]. Western small-footed myotis prefers to feed on small moths, but consumes a variety of small flying insects, including small flies, true bugs, and beetles [19], [64]. Western small-footed myotis returns to its night roost or maternity site to rest after foraging, and then departs for additional foraging a few hours before dawn [19].

Mating takes place in fall or winter, and small nursery colonies are formed in the spring [19], [63]. Western small-footed myotis has low reproductive rates, with a single offspring born between mid-June and late July [19], [63].

A hardy species, western small-footed myotis is one of last species to begin hibernation and one of the first to leave its hibernacula [64], [302]. Western small-footed myotis is thought to hibernate singly or in small groups in the general area of its summer range [19].

Yuma Myotis (*Myotis yumanensis*)

Range		***Conservation***[1]	***Legal***[2]
Provincial	AB	-	-
	BC	S5 (Secure)	-
	MB	-	-
	NB	-	-
	NL	-	-
	NS	-	-
	NT	-	-
	NU	-	-
	ON	-	-
	PE	-	-
	QC	-	-
	SK	-	-
	YT	-	-
Federal		-	-
Global		LC (Least Concern)	N/A

[1] Provincial ranking from NatureServe; Federal ranking from COSEWIC [283]; Global ranking from IUCN [20].
[2] Provincial listing under applicable provincial law; federal listing under SARA [44].

Key Identification Features

The Yuma myotis (*Myotis yumanensis*) has short, dull fur which can be pale brown to almost black (for individuals in the interior of British Columbia and individuals on the coast, respectively) [19]. Yuma myotis has lighter fur on its abdomen and dark brown wings, ears, and snout [19]. The Yuma myotis has relatively short ears, and its calcar is not keeled [19]. It can be difficult to distinguish between the Yuma myotis and the little brown myotis [19]. Key identification features of Yuma myotis include [19]:

- Ears are relatively short and dark brown;
- Fur on body is pale brown to almost black on back and lighter on abdomen;
- Forearm length: 30 to 38 mm;
- Body length: 60 to 99 mm;
- Ear length: 9 to 16 mm; and
- Wingspan: 21 to 25 cm.

Range

The Yuma myotis is found in western North America, from the northern limit of its distribution in southern British Columbia south to central Mexico, and east to Montana and western Texas [19], [21], [303].

Population Numbers

The Yuma myotis is globally common and global population levels are stable; however, Yuma myotis may be threatened by riparian area habitat loss [21], [66]. Within Canada, the Yuma myotis may be considered locally abundant, but is typically not regionally common [19].

Habitat Preferences

The Yuma myotis can be found in a variety of habitats, including juniper and riparian woodlands, and deserts with open water [66]. Yuma myotis is closely associated with streams, rivers, ponds, and lakes [66]. The Yuma myotis is typically found in arid habitats with a water source, and between 0 and 730 m in elevation [19]. Yuma myotis roosts by the thousands in caves, attics, abandoned mines, buildings, and under bridges [66]. Little is known about its winter migration patterns, or where it roosts in the winter [66].

Foraging and Breeding Behaviour

As Yuma myotis is closely associated with water, they primarily forage over water in forested areas, eating soft-bodied, flying insects [19], [21]. Individuals of Yuma myotis are efficient insectivorous bats that can fill their stomachs entirely in only 15 minutes [19].

The Yuma myotis mates in autumn and stores sperm until ovulation in the spring, when it forms maternity colonies that are usually close to foraging colonies [21]. Females begin breeding in their second summer; younger females tend to produce female pups in late June, while older females tend to have male pups earlier in the season [19]. Yuma myotis are easily disturbed when they have young and have been known to carry their offspring with them to move them to a quieter roosting spot [19].

APPENDIX B – STATUS RANKS AND DESCRIPTIONS

Table B-1 NatureServe/Conservation Data Centre (CDC) Subnational Conservation Status Ranks and Descriptions[a]

Status	Definition
SX	**Presumed Extirpated** - Species or community is believed to be extirpated from the province. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
SH	**Possibly Extirpated (Historical)** – Species or community occurred historically in the province, and there is some possibility that it may be rediscovered. Its presence may not have been verified in the past 20-40 years. A species or community could become NH or SH without such a 20-40 year delay if the only known occurrences in a province were destroyed or if it had been extensively and unsuccessfully looked for. The NH or SH rank is reserved for species or communities for which some effort has been made to relocate occurrences, rather than simply using this status for all elements not known from verified extant occurrences.
S1	**Critically Imperiled** - Critically imperiled in the province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province.
S2	**Imperiled** - Imperiled in the province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state/province.
S3	**Vulnerable** - Vulnerable in the province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.
S4	**Apparently Secure** - Uncommon but not rare; some cause for long-term concern due to declines or other factors.
S5	**Secure** - Common, widespread, and abundant in the province.
SNR	**Unranked** - Province conservation status not yet assessed.
SU	**Unrankable** - Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.

Table B-1 NatureServe/Conservation Data Centre (CDC) Subnational Conservation Status Ranks and Descriptions[a]

Status	Definition
SNA	**Not Applicable** - A conservation status rank is not applicable because the species is not a suitable target for conservation activities.
S#S#	**Range Rank** - A numeric range rank (e.g., S2S3) is used to indicate any range of uncertainty about the status of the species or community. Ranges cannot skip more than one rank (e.g., SU is used rather than S1S4).
Not Provided	Species is not known to occur in this province. Contact the relevant natural heritage program for assigned conservation status.
	Qualifiers
Qualifier	**Definition**
B	**Breeding**[b] - Conservation status refers to the breeding population of the species in the province.
N	**Nonbreeding** - Conservation status refers to the non-breeding population of the species in the province.
M	**Migrant** - Migrant species occurring regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. Conservation status refers to the aggregating transient population of the species in the province.
?	**Inexact or Uncertain** - Denotes inexact or uncertain numeric rank. (The "?" qualifies the character immediately preceding it in the S-rank.)

[a] NatureServe or CDC definition of conservation status rank obtained from http://explorer.natureserve.org/nsranks.htm
[b] Note: A breeding status is only used for species that have distinct breeding and/or non-breeding populations in the province. A breeding-status S-rank can be coupled with its complementary non-breeding-status S-rank if the species also winters in the province, and/or a migrant-status S-rank if the species occurs regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. The two (or rarely, three) status ranks are separated by a comma (e.g., "S2B, S3N" or "SHN, S4B, S1M").

APPENDIX C – BAT USE OF HABITAT AND LANDSCAPE FEATURES

C.1. Forests

Forests are an important influence on some species of bats in Canada, with species demonstrating varied responses to forest management and structure. Bats utilize forests in various ways including foraging and using trees for roosts, maternity roosts, or hibernacula. In addition, some associations with forests may be regional. For example, in the Pacific Northwest little brown myotis have been observed using root complexes as hibernacula [112]. Some species respond positively to intact forests, whereas others respond positively to more varied habitat structure and may show negative responses to intact forest. For example, selective logging of white pine forests greatly decreases canopy closure and densities of large trees and snags (i.e., standing dead trees), resulting in reduced use by most bat species [231]. At a larger spatial scale, several species tend to be associated with more open and/or fragmented forests [231], [284], [288].

C.2. Abandoned mines/caves

Abandoned mines and caves used by bats as hibernacula have the potential to concentrate bat activity around entrances during the emergence from (mid-March to May), and return to (September to November) hibernacula depending on the region [292]. Abandoned mines and caves used by bats as hibernacula also have the potential to concentrate bat activity around entrances during swarming (i.e. nocturnal flights through hibernacula) periods of the bat life cycle (e.g., typically August to September in eastern Canada [289]). The degree of shelter at the entrances, and the total length of the rivers in the local landscape, may also be important factors in predicting swarming activity levels at abandoned mines and caves [289].

C.3. Wetlands

Wetlands may concentrate bat species by providing them with foraging habitats. Bats have been found to be more active in wetland and riparian habitats compared to the surrounding forest. In one study, there was an abundance of beetle and fly species in wetland habitats compared to other habitats, which may have contributed to the increased bat activity observed in these areas [304]. The extent of shrub or tree cover in riparian areas has also been found to influence habitat use by bats [305].

C.4. Open water/waterbodies (aquatic resources)

Open water/waterbodies (aquatic resources) may be an important influence on some species of bats in Canada. Bats have been found to be more active over lakes than over streams or fields [306], and bat activity has been shown to be greater near water (5 m) than away from water (150 m) in small-scale studies [307]. Some species such as big brown bat have been observed roosting in proximity to waterbodies [308]. Bats have also been found to concentrate in open water areas distant from shorelines. One study off the mid-Atlantic coast demonstrated that bat activity, consisting mainly of eastern red bat, did not change with the distance from the shoreline, at least to a distance of 22 km or the maximum distance assessed [309].

C.5. Ridgelines

Ridgelines may concentrate some bat species by providing additional roosting sites or helping with navigation during migration periods. In southern Alberta, activity of silver-haired bats was found to be higher near the foothills of the Rocky Mountains than on the prairie grasslands [113]. This concentration may be due to the presence of roosting sites in the foothills, combined with a lack of roosting sites on the prairie grasslands, or the potential for ridgeline features to act as navigational landmarks along migratory paths. The ridgeline features may be particularly important for long-distance migratory bat species in helping with navigation during their migration period.

C.6. Rock habitat / talus slopes

Rock habitat/talus slopes can be an important influence on some species of bats in Canada. Rock habitat and talus slopes may concentrate certain bat species during roosting and hibernation periods, particularly for eastern small-footed myotis, which is known to use these habitats. Eastern small-footed myotis has been observed roosting at ground-level in talus slopes and rock fields, and in vertical cliff faces [310], [311]. In one study, roosts were located close to vegetation in areas with low canopy cover, and roosts used by female bats were typically closer to ephemeral water sources than those used by male bats [310]. In late winter months, bats have been observed in a state of torpor in talus slopes, indicating that they may also overwinter in these habitats [311].

C.7. Shorelines / peninsulas

Shorelines and peninsulas appear to concentrate long-distance migratory bat species as they follow the general orientation of the landscape during movements.

An increase in abundance of hoary bat and silver-haired bat were found between June and August at Long Point Provincial Park, Ontario, suggesting that the park may act as a migratory flyway for these species, possibly due to the east-west orientation of the peninsula that may concentrate migrating bats (similar to birds) in this area [312]. Similarly, Barclay reported behaviour of migrating bats at the Delta Marsh in Manitoba where hoary bat, silver-haired bat, and eastern red bat appeared to follow the shorelines of Lake Manitoba [98]. Certain Nova Scotia bats (i.e., silver-haired bat, eastern red bat, hoary bat, little brown myotis, northern myotis, and tri-colored bat) appear to concentrate their movements along islands off the southwest coast in the fall season [313]. This may be due to the orientation of Nova Scotia, which may also cause a funnelling effect for long or mid-distance migrants.

C.8. Building density

Buildings (primarily abandoned and occupied homes, barns, and garages) may provide additional roosting habitats for the bats and as a result may concentrate activity within areas with at least some buildings. Many common bats (e.g., big brown bat) roost in buildings, and bats in Canada have been found to be more active in rural areas with buildings than in uninhabited forest areas without buildings [306]. Some bats, most notably little brown myotis use buildings as maternity colonies [306], whereas most others use buildings only as roosts.

C.9. Roads

Roads can be an important influence on some bat species in Canada. Roads may concentrate bats by acting as travelling corridors and/or foraging areas, and roosting sites may be selected in proximity to roads as a result. Roads have been shown to provide corridors for bats commuting between roosting and foraging sites [307]. Some bats, including northern myotis and eastern red bat, have been shown to be more likely to roost close to roads, whereas tri-colored bats are more likely to roost further away from roads [308].

APPENDIX D – WHITE-NOSE SYNDROME

D.1. Current impacts and distribution of WNS

White-nose syndrome was first encountered in North America in eastern New York during the winter of 2006/2007 [11], and then in Canada during the winter of 2009/2010 [123]. There have now been confirmed cases of WNS in 31 U.S. states and five Canadian provinces (New Brunswick, Nova Scotia, Prince Edward Island, Quebec, and Ontario) [11].

White-nose syndrome is estimated to have killed over 6 million insect-eating bats in North America over the past 10 years [10], [11]. All hibernating North American bat species are considered susceptible hosts to WNS [95], [314], with the myotis genus representing approximately 64% of all WNS hosts [95]. In Canada, from 2010 to 2012, tri-colored bat declined by 94%, little brown myotis declined by 94 to 99%, and northern myotis declined by 90% [123]. Maritime bat populations have been reduced by 98.5% over three years from 2012 to 2015 primarily due to WNS [315].

The first known occurrence of WNS in bats in Ontario was in the winter of 2009 to 2010 in the Bancroft-Minden area, about 200 km west of Ottawa [10]. In Ontario, most bat hibernacula are confirmed or suspected to be infected with Pd [10]. WNS-affected bat colonies in Ontario have declined by up to 95 to 100% over the past two to three years since detection of Pd [249]. Bat species most affected in Ontario include little brown myotis, northern myotis, and eastern small-footed myotis [249]. Other bats that do not regularly dwell in caves are not affected including eastern red bat, hoary bat, and silver-haired bat. Eastern small-footed myotis may be less susceptible to WNS than other Ontario resident (year-round) bat species, since they tend to hibernate alone or in smaller groups and hibernate in colder, drier parts of the caves, which are less prone to the disease [316], [317].

The first occurrence of WNS in bats in Quebec was confirmed in March 2010 at the Caverne Lafleche in the Outaouais region [10]. White-nose syndrome was then documented throughout the western portion of the province. The first occurrence in New Brunswick (in a cave in Albert County near Moncton) and Nova Scotia (in a day-flying bat near Brooklyn, Hants Co.) was in March 2011 [10]. Since then, Pd has spread throughout New Brunswick, Nova Scotia and Prince Edward Island.

Certain environmental conditions are associated with elevated levels of bat fatality due to WNS. North American bats tend to hibernate at sites with high temperatures (3 to 15 °C) and high humidity (90%) [249], [318]. The fungus grows in temperatures less than 20 °C and infects bats by causing most physiological damage when their body temperatures are supressed during hibernation [318], [319]. Bat body temperatures tend to be 2 to 10 °C during hibernation, which is in the range of optimal fungal growth [237]. Bat mortalities tend to be mostly associated with dehydration and in winter/colder conditions due to frozen/inaccessible water sources. Bats have been found to survive WNS by metabolically warming bodies to euthermic temperatures (35 °C) and seeking warm conditions or attaining food [318]. Conversely, in the warmer/wetter climates of European countries, WNS had been documented, however, not linked to fatality events [319]. Twelve European countries have documented WNS in bat lesions or similar signs [319]. Reductions in hibernacula temperatures could reduce optimal temperatures for this disease and/or moderate the spread of the disease through infected bats.

Environmental conditions including air temperature, elevation and precipitation have also been shown to influence WNS fatality levels. For example, the probability of fatality due to WNS increases with elevation and topographic heterogeneity [318]. The WNS fungus has been found to survive in previously infected caves that no longer support bat species (i.e., in bird feathers, mammal hair/skin, arthropod remains in guano, dead moss), so there is potential for caves to act as WNS reservoirs [237], [320]. This fungus can remain in hibernacula throughout the summer, re-infecting bats in the fall upon return to their hibernacula [237], [320].

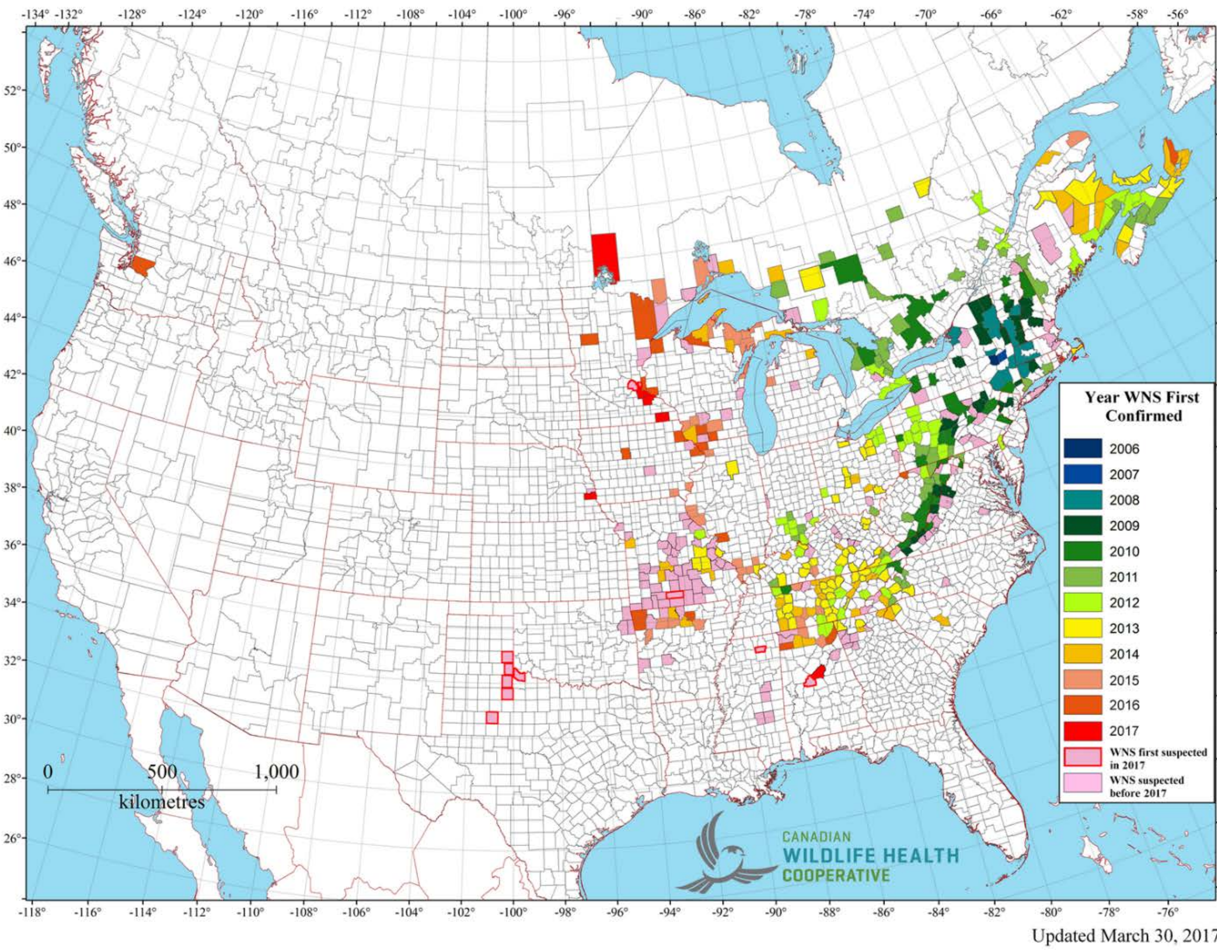
The first case of WNS in western North America was confirmed in a little brown myotis individual found near North Bend, Washington, U.S. [11]. The disease in this bat was confirmed through fungal culture, molecular and pathology analyses, tested by the USGS National Wildlife Health Centre. This occurrence of WNS is approximately 1,300 miles west of the previously known westernmost detection of WNS in North America. In addition, in March 2017 the fungus was confirmed for three species in northern Texas, the tri-colored bat, cave myotis (*Myotis velifer*), and Townsend's big-eared bat [321]. These occurrences of WNS were the first recorded detections of the fungus in both the cave myotis and the Townsend's big-eared bat.

D.2. Predicted impacts and spread of white-nose syndrome

Current field surveys indicate that impacted bats in North American hibernacula are starting to show behavioural adaptations to WNS, by forming smaller and less condensed bat colonies [322]. Bats often form tight clusters for hibernation, and if infected with WNS, facilitate the transmission of the disease to other bats in these clusters [320]. Bats also often engage in "swarming" behaviours at hibernacula before hibernation, further facilitating the spread of this disease [320]. Bat to bat transmission is the primary mode of transmission of this disease [249]; however, WNS can also be spread by people who visit caves and abandoned mines and get the fungus spores on their clothing. The public has been advised not to visit non-commercial caves to help prevent clothing transmission, as well as the potential to arouse bats with noise [249].

Most affected bat species are long-lived and have naturally low reproductive rates, typically bearing only one offspring annually (reducing the likelihood of recovering affected populations) [249], [322]. As a result, rapid disease transmission and slow population recovery are anticipated from this disease. It is unknown if bats pass the fungus onto their offspring during the maternity period, however, this is unlikely since the prevalence of WNS drops over the summer season, as temperatures increase [323].

The Canadian Wildlife Health Cooperative (CWHC) conducts WNS testing and maintains a national database and mapping of the extent of the disease in Canada [10]. The current distribution of WNS in Canada and the U.S. is shown on Figure D-1, and the current distribution of WNS in Canada is shown on Figure D-2.



Source: CWHC [10]

Figure D-1. Distribution of WNS in Canada and the United States, as of 30 March 2017.

White-nose syndrome is estimated to have killed over 6 million insect-eating bats in North America over the past 10 years by causing the bats to wake up during hibernation and use valuable excess energy reserves at this time, resulting in potential dehydration and starvation [10], [11], [123]. During hibernation, bats enter into a state of torpor, in which they lower their body temperatures to the surrounding air temperatures and reduce their heart rates. White-nose syndrome affects sleep patterns of hibernating bats, waking them up during the day or in the winter when they would typically be hibernating. Bats whose hibernation is disrupted may prematurely expend energy otherwise necessary to maintain them throughout the winter [95], causing some to dehydrate or starve to death [123]. Some bats, both at an individual and species level, appear to be more susceptible to WNS than others. The fungus has affected little brown myotis, big brown bat, small-footed myotis, northern myotis, tri-colored bat and Indiana bat [249], [324]. Bat species that are most susceptible to WNS (e.g., little brown myotis) exhibit high rates of evaporative water loss compared to less susceptible species, which can cause dehydration [325]. White-nose syndrome also causes inflammation in little brown myotis which may affect torpor behaviour or cause damage upon emergence in the spring [326].

Due to the negative impacts of WNS on bat populations, the need to reduce further impacts may be achieved through use of prophylactic or curative agents (inoculation of caves), controlling spread through biological or chemical means, protecting, enhancing, and decontaminating roost areas, and increasing understanding of the disease. Compensation and offset options for the potential impacts of wind energy facilities may therefore focus on providing support to reducing the impacts of WNS on local bat populations.

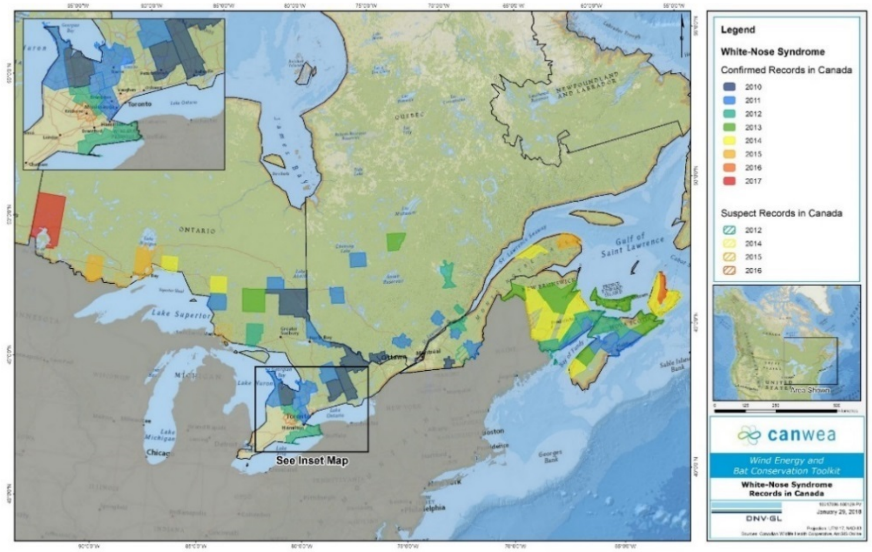


Figure D-2. Confirmed and Suspected Records of White-nose Syndrome in Canada, by Municipality, as of 30 March 2017.[11]

[11] Up-to-date white-nose syndrome records can be accessed online at https://www.whitenosesyndrome.org.

APPENDIX E – FATALITY ESTIMATORS

The sections below provide detailed descriptions of five statistical fatality estimators considered in Section 3 of the Review. They summarize assumptions, benefits, limitations, and biases of each estimator. Each section concludes with a brief description of considerations for use of the estimator at a wind energy facility.

E.1. Jain Estimator

The Jain estimator [87] can be defined as the following [92]:

(3) $$n = \frac{c}{s * p}$$

Where:
n = estimated number of fatalities
c = number of fatalities actually found
s = the proportion of carcasses not scavenged after half the length of the search interval
p = proportion of carcasses found by a searcher

E.1.1. Assumptions

The Jain estimator makes the following assumptions [69], [80], [92], [327], although it is unclear if there are additional assumptions [70]:

- this estimator assumes single day searcher efficiency (i.e., no bleed-through);
- a single searcher efficiency value that is constant over time;
- the scavenger removal rate assesses the proportion of carcasses remaining after half the length of the search interval (carcass removal rate is constant throughout the search interval); and
- the probability of a collision event is constant over all days of the monitoring season.

E.1.2. Benefits, Limitations, Biases

A single day searcher efficiency rate (i.e., no bleed-through) has the potential to overestimate the fatality rate [328]. In reality, a searcher has repeated opportunities to find a carcass missed on the first search event (if average carcass persistence is greater than the search interval). Despite an opportunity to find missed carcasses on subsequent visits, each carcass likely becomes more difficult to find over time, thereby causing a reduction in the searcher efficiency over time.

The scavenger removal rate is calculated differently than in other estimators, with this being the calculation of the proportion of carcasses remaining after half the length of the search interval. As a result, data collected for use in this estimator is different than what is required for other estimator equations, therefore additional monitoring effort would be required to collect scavenger removal data if this estimator is planned to be used in combination with other estimators.

The probability of a collision event is assumed to be constant over the monitoring season; however, the probability of collision is not likely constant, as it is likely to change with factors such as weather conditions, movement patterns, season, or life cycle stages of the species or species group.

The Jain estimator would likely bias the fatality rate high, because the searcher efficiency rate is not derived over multiple search days, and therefore does not account for additional opportunity to find missed carcasses or the anticipated decline in searcher efficiency as a function of carcass age on subsequent search events.

E.1.3. Implementation Considerations

With a no bleed-through approach, staff effort and cost would be increased to retrieve carcasses at the end of each searcher efficiency trial day (i.e., carcasses would be retrieved at the end of the day rather than being placed and monitored until they are found). This would have implementation implications when designing a protocol, as it would require slightly higher labour effort than trials in which test carcasses are left in the plots.

E.2. MNRF Adapted Estimator

The Ontario MNRF guidance document, *Bats and Bat Habitats: Guidelines for Wind Power Projects* [88], outlines the requirements for post-construction bat fatality monitoring in Ontario. This guidance document has been developed over several years, including multiple iterations of provincial guidance prior to the current guideline [329], [330].

This estimator recommended by the MNRF appears to have originated from the California Energy Commission's *California Guidelines to Reduce Impacts to Birds and Bats from Wind Energy Development* [93]. This estimator is not widely used elsewhere in North America.

The MNRF adapted estimator [88] can be defined as the following:

(4)

$$C = \frac{c}{S_{EO} * S_C * P_S} \quad \mathrm{C} = \frac{\mathrm{c}}{\mathrm{S_{EO}} * \mathrm{S_C} * \mathrm{P_S}}$$

Where:

C = estimated number of fatalities

c = number of fatalities actually found

S_{EO} = weighted proportion of carcasses expected to be found by searchers (overall searcher efficiency)

S_C = proportion of carcasses remaining over a pre-determined length of time (i.e., a set number of search intervals)

P_S = proportion of area searched

E.2.1. Assumptions

The MNRF adapted estimator makes the following assumptions [88]:

- scavenging activity is linear (i.e., a carcass is equally likely to be scavenged over the duration of time that it is present within the search area, and scavenging occurs at a linear rate over the pre-determined length of time [i.e., a set number of search intervals]);
- the start of the monitoring season begins with no carcasses in the search area;
- a single searcher efficiency value, which is applied to every search day;
- all searchers achieve the average searcher efficiency rate;
- all carcasses have an equal probability of being scavenged despite potentially occurring at different times within the search interval;
- each search is conducted at the same rate of efficiency, where carcasses are present in the search area for only a single search day and are not available to be found on subsequent search days; and
- Carcasses fall equally throughout the search area.

E.2.2. Benefits, Limitations, Biases

The MNRF adapted estimator recommends a search interval of twice weekly, or every 3 to 4 days. The recommendation appears to have been derived from the California Energy Commission's (CEC) *California Guidelines to Reduce Impacts to Birds and Bats from Wind Energy Development* [93], which recommends a search interval of once every two weeks. The CEC guidelines also recommend that if the search interval deviates from this recommendation, the estimate be adjusted to account for this variation. However, the MNRF *Bats and Bat Habitats: Guidelines for Wind Power Projects* [88] does not provide a process for adjusting fatality estimates derived from this equation. Therefore, it is likely that fatality estimates for projects in Ontario that utilize the MNRF adapted estimator are not an accurate portrayal of true fatality rates.

The MNRF adapted estimator limits the scavenger trial duration to the time of "complete decomposition", which is described by MNRF as typically two weeks for small carcasses in Ontario [88]. The MNRF adapted estimator also uses an average probability of persistence over a pre-determined length of time (i.e., a set number of days) rather than average time to removal [88]. The assumption that scavenging rate is a linear function of time is not likely the case as fresh carcasses will likely be more appealing to scavengers, becoming less appealing the longer they persist in the search area [69], [70], [75].

Each carcass will have a different probability of being scavenged prior to the next search event, as they appear at varying times throughout the search interval and experience varying degrees of weathering, decomposition, or availability for scavenger removal [76]. Although present, this potential bias may be minimized with more frequent search intervals (i.e., weekly or twice-weekly). However, with more frequent search intervals observers are more likely to find carcasses deposited prior to the previous search, in which case carcasses would be double counted and therefore fatality estimates would be overestimated.

The MNRF adapted estimator assumes that no bleed-through (i.e., undiscovered fatalities from one search to another) occurs and that every carcass found is newly arrived since the previous search event. However, carcasses may be missed on the first search day, but later found on a subsequent search day and carcasses will likely become more difficult to find over time due to decomposition or settling [76]. As a result, this equation may overestimate fatality when searcher efficiency is low and carcass persistence is high (i.e., carcasses are removed infrequently), even when search intervals are short [69], [82].

This estimator assumes that fatalities fall equally throughout the search area. However, the density of bat fatalities is known to decrease with distance from the turbine base [70], [331]. This estimator does not account for the density of carcasses decreasing with distance from turbine and that unsearched areas (typically due to dense vegetation) often tend to be further away from the turbine. Although unsearched areas may be those with the lowest probability of encountering a carcass, the proportion of area searched variable assumes equal distribution, which could lead to fatality overestimates [69], [80].

Overall, the MNRF adapted estimator would likely bias the fatality rate high when searcher efficiency is low and carcass persistence is high. Low searcher efficiency (e.g., probability of detection = 0.1 – 0.3) is typical of bat fatality monitoring due to the small size and colouration of the majority of bat carcasses.

E.2.3. Implementation Considerations

Implementing the search protocol required by the MNRF adapted estimator will require significant staff time and effort. The MNRF adapted estimator requires a 3 to 4 day search interval, which is more frequent than the 14 day search interval recommended by the CEC's *California Guidelines to Reduce Impacts to Birds and Bats from Wind Energy Development* [93] from which it was derived. Because searches occur roughly every four times as frequently under the MNRF adapted estimator protocol than under the CEC protocol, and are required for a minimum of three years, the resulting financial burden for projects can be significant.

The proportion area searched is also calculated for this estimator. This variable is calculated by mapping search areas into visibility classes according to specific criteria in the guideline [88]. Certain areas may be deemed "unsearchable" according to the guideline criteria; however, these areas may actually be somewhat searchable. In an effort to increase the proportion area searched, search areas may be cleared, which can increase the cost and clearing effort for the wind energy facility.

With a no bleed-through approach to the searcher efficiency trial, staff effort would be increased to retrieve carcasses at the end of a searcher efficiency trial day (i.e., carcasses would be retrieved at the end of the day rather than being placed and monitored until they are found). This would have cost and effort implications when designing a protocol.

E.3. Shoenfeld-Erickson Estimator

The Shoenfeld-Erickson estimator [84] can be defined as the following [69], [92]:

(5)
$$n = \frac{c}{\frac{t*p}{I} * \frac{e^{\left(\frac{I}{t}\right)}-1}{e^{\left(\frac{I}{t}\right)}-1+p}}$$

Where:

n = estimated number of fatalities

c = number of fatalities actually found

t = average time of carcass removal in days

p = proportion of carcasses found by a searcher

I = average interval between searches in days

This estimator uses Monte Carlo/bootstrapping statistical methods for estimating confidence intervals [80].

E.3.1. Assumptions

The Shoenfeld-Erickson estimator makes the following assumptions [69], [76], [92]:

- regular search intervals – an earlier version of this equation used the Poisson statistical process, which assumes an average time between searches;
- exponential carcass removal rate using an average length of time (in days) until a carcass is removed from the search area;
- a single searcher efficiency value, which is applied to every search day;
- all searchers achieve the average searcher efficiency rate;
- all carcasses (old and new) have the same probabilities of discovery (discovery failures are entirely random with respect to carcass age);
- the lengths of search intervals, rates of fatality, scavenger removal and searcher efficiency are approximately constant over time intervals; and
- bleed-through is assumed to occur all of the time.

E.3.2. Benefits, Limitations, Biases

This estimator assumes exponential carcass removal, which makes the estimator sensitive to changes in removal times [76], [80], [92], [327]. This exponential distribution of carcass removal is likely more realistic than a linear distribution, as fresh carcasses will likely be more appealing to scavengers, becoming less appealing the longer they persist in the search area (decaying, decomposing over time).

A single searcher efficiency value is restrictive, as searcher efficiency is likely to vary over time, season, habitat types, search conditions, and among different searchers. A single searcher efficiency value applied in this estimator is better suited for shorter search intervals.

The Shoenfeld-Erickson estimator is based on the assumption that observers have the ability to find carcasses on subsequent search days, and therefore this estimator incorporates the expectation of bleed-through [69]. However, it is assumed that the search detection rate does not change over time (i.e., all carcasses, old and new, have the same probability of discovery) [76], which may not be the case since it is believed that carcasses that have been overlooked once are more likely to be overlooked on subsequent visits, especially as they decompose.

The Shoenfeld-Erickson estimator biases the estimated fatality rate low, when carcass persistence and searcher efficiency variables deviate from constant over time [70].

E.3.3. Implementation Considerations

A single searcher efficiency measure can be implemented more easily and results obtained more readily than longer or multiple searcher efficiency trials. In addition, applying a bleed-through approach to searcher efficiency trials can reduce staff effort, as carcasses are placed and monitored until they are found, and do not require retrieval after each searcher efficiency trial day. This approach is also more reflective of the ability of searchers, allowing them to find carcasses on subsequent search days.

E.4. Huso Estimator

The Huso estimator [70] can be defined as the following [92]:

(6)

$$n = \frac{c}{\frac{t * p}{\min(\tilde{I}, I)} \left\lfloor 1 - e^{\left(-\frac{\min(\check{I}, I)}{t}\right)} \right\rfloor * \min\left(1, \frac{\check{I}}{I}\right)}$$

Where:
n = estimated number of fatalities
c = number of fatalities actually found
t = average time of carcass removal in days
p = proportion of carcasses found by a searcher
I = average interval between searches in days
Ĩ = effective search interval (-log(0.01)*t)

The Huso estimator introduces an effective search interval, which corrects for cases where a carcass may have been missed during a search event when its probability of persistence is very low (i.e., <1%) [70].

E.4.1. Assumptions

The Huso estimator makes the following assumptions [69], [70], [76], [80], [92]:

- carcass persistence can be modified for observed distributions (e.g., exponential, Weibull, log-logistic, log normal); and
- a single day searcher efficiency and scavenger removal rate (i.e., no bleed-through).

E.4.2. Benefits, Limitations, Biases

The Huso estimator can be used with various types of persistence distributions including exponential, Weibull, log logistic, and log normal distributions [327]. This estimator also allows the incorporation of covariates into the estimates of searcher efficiency, which facilitates calculations of different searcher efficiencies for different seasons, search conditions, habitat types, and searchers. The Huso estimator also calculates per-turbine fatality estimates, which better incorporates among-turbine variance into the overall fatality estimate than other approaches.

The Huso estimator works well when carcass persistence times are long (average 32 days) and usually when search intervals of >14 days are used [82]. However, Korner-Nievergelt et al. reported that when carcass persistence times are shorter (an average of 4.2 days used in their analysis) and search intervals are shorter (usually 1 to 7 days), this estimator was found to overestimate the number of fatalities [82].

The searcher efficiency rate is for a one-time search and a carcass missed on the first search has no possibility of detection on subsequent search days (i.e., no bleed-through) [69]. However, in reality if the average carcass persistence time is longer than the search interval, it is likely that a searcher will have an opportunity to find a carcass on subsequent visits and in this case the number of fatalities may be overestimated [69], [82].

This estimator is useful for long search intervals, as it accounts for carcasses that may be missed when the likelihood of them persisting between search intervals is very low (<1%), in the effective search interval [70].

The Huso estimator may bias the fatality rate high or low, depending on searcher efficiency and scavenger removal variables. Specifically, this estimator may bias the fatality rate high, when carcass persistence is low and during shorter search intervals; however, it may bias the fatality rate low when carcass persistence is high.

E.4.3. Implementation Considerations

With a no bleed-through approach, staff effort would be increased to retrieve carcasses at the end of a searcher efficiency trial day (i.e., carcasses would be retrieved at the end of the day rather than being placed and monitored until they are found). This would have implementation considerations when designing a protocol.

E.5. Wolpert Estimator

The Wolpert estimator [76] can be defined as the following:

(7)

$$n = \frac{c}{\frac{t*p}{I} * \frac{e^{\left(\frac{I}{t}\right)} - 1}{e^{\left(\frac{I}{t}\right)} - \theta * (1-p)}}$$

Where:
n = estimated number of fatalities

c = number of fatalities actually found
t = average time of carcass removal in days
p = proportion of carcasses found by a searcher
I = average interval between searches in days
θ= proportion of undiscovered carcasses that remain discoverable

E.5.1. Assumptions

The Wolpert estimator makes the following assumptions [76], [327]:

- there is a partial bleed-through. The proportion of undiscovered carcasses assumed to remain discoverable in future searches is addressed by the equation;
- allows for a variable scavenger removal trial length, suggesting a 60-day “preliminary scavenger removal trial” in order to determine the most appropriate search interval and combined detection probability trial length; and
- carcass persistence can be modified for observed distributions (e.g., exponential, Weibull, log-logistic, log normal).

E.5.2. Benefits, Limitations, Biases

The Wolpert estimator approach to searcher efficiency is more realistic as it accounts for a proportion of carcasses that may have been missed by a searcher (i.e., bleed-through) and are still in a discoverable condition (i.e., less decay, decomposition).

The 60-day scavenger removal trial would allow for a site-specific carcass persistence rate, for all carcasses persisting less than 60 days. This must be generated through field sampling procedures that produce time-dependent carcass persistence and searcher efficiency rates in order to produce unbiased results using either short or long search intervals [76]. A benefit to this trial is that all of the values necessary for this estimator are obtained in this one 60-day trial period. However, this trial would have to occur in the appropriate season (spring to fall) and could delay the start of the fatality monitoring program by one year, while incurring additional cost. However, alternate placement measures may be planned in advance (e.g., outside of the project area, but within similar areas and habitats representative of the project area) and implemented in conjunction with the fatality monitoring season, or during the construction period. The trial also uses the same carcasses for both searcher efficiency and scavenger removal trials (combined) and uses a multi-day searcher efficiency value (i.e., one value applied to all search days instead of having separate values based on season, habitat types). A potential weakness of this approach is that some large carcasses may persist beyond the end of a 60-day trial, and it may be necessary to extend the trial to get accurate bleed-through estimates in these cases.

E.5.3. Implementation Considerations

The 60-day scavenger removal trial could delay the fatality monitoring by one year. As a result, this would increase staff effort, overall project time, cost, and would likely not be acceptable to most regulatory agencies. However, proper trial length and search intervals can be established for the main monitoring program from these results if carefully tailored to the circumstances.

E.6. FatalityCMR Estimator

The FatalityCMR estimator [83] can be defined as the following:

(8) $$N_{Tot} = N_0^{(1)} + N_0^{(2)} + \sum_{i=1}^{T-1} N_i^{(1)}$$

Where:

N_{Tot} = superpopulation size

$N_0^{(1)}$ = number of carcasses of age 1 already on the ground immediately before the first sampling occasion

$N_0^{(2)}$ = number of carcasses of age 2 already on the ground immediately before the first sampling occasion

$N_i^{(1)}$ = number of new carcasses that appear between sampling occasions i and i + 1 and that are still available for detection at time i + 1, i = 1…T-1

T = number of sampling occasions

The FatalityCMR estimator is based on a complex method requiring multiple transition matrices and is not easily calculated without using the FatalityCMR software. The FatalityCMR estimator fits a multistate superpopulation capture-recapture model to raw carcass count data [83], [332]. Model inputs include data on fatality searches, persistence trials, and detection trials, which are used to generate estimates of total fatalities. The software allows users to specify individual turbine conditions including those that that can affect searcher efficiency and scavenger removal rates (e.g., different vegetation cover under turbines) or potential collision risk (e.g., turbine model). There is also a function to specify carcass age-class or state (e.g., “fresh” vs. “old’) for carcasses found during searches or used during trials. A maximum of two carcass states can be defined for each study (e.g., fresh vs. dry, intact vs. partially-scavenged).

If a fatality is rare or of a protected species, the software has the option to switch to an “evidence of absence” mode and estimate the probability of not finding a carcass. In cases where fatalities are expected to be rare, the Huso Evidence of Absence estimator [333] is an estimator designed specifically for rare events and can be used to aid in the design of rare-events monitoring.

E.6.1. Assumptions

The FatalityCMR estimator makes the following assumptions [83]:

- there is bleed-through;
- consistent search protocols. If different turbines are subjected to different search protocols (interval, number of searches) a separate data file per type of search protocol will have to be entered and analysed separately. Similarly, all trial carcasses must be subjected to the same protocol, checked on the same days (e.g. one check every two days for 10 days); and

- each fatality event is independent of others.

E.6.2. Benefits, Limitations, Biases

The FatalityCMR estimator has the potential to provide less biased results due to the software's ability to account for time and age variations in all parameters and due to the assumption of bleed-through [83].

This estimator calculates the maximum number of carcasses that could have escaped detection with a user-defined error probability, by default this is set to 0.05. This corrects for carcasses that may get missed or scavenged. In practice, setting this value to 0.05 may prove overly conservative given the inherent variability of conditions during a fatality study.

The software does not allow for varying protocols at different turbines, searcher efficiency, or scavenger removal trials. There is no flexibility in the program for missed search days due to inclement weather, temporary inaccessibility, or other safety concerns. This can be limiting as some events may be unpredictable throughout the fatality monitoring period, and it is indeed an unusual event for an entire fatality monitoring study to be performed as planned without any deviations.

E.6.3. Implementation Considerations

This estimator requires that a particular survey protocol be set in place. This may be limiting in certain circumstances throughout the monitoring period (i.e., turbine cannot be searched on a given day, trial carcasses missed on a given day). It is also difficult to use in studies in which any aspects of the study, such as number or identity of turbines searched, number of searchers, or search frequency change among seasons or years. Such changes are common, for example, in areas where bat fatalities are less likely in winter, and searches are therefore modified during this season.

APPENDIX F – CURTAILMENT STUDIES

F.1. Feathering vs. Free-wheeling Below Manufacturers' Cut-in Speed

The sections below provide detailed descriptions of studies that have examined the effectiveness in reducing bat fatalities by feathering wind turbines below manufacturers' cut-in speed compared to allowing the turbine to free-wheel, as described in Section 4 of the Review. These studies are summarized in the sections below and in Tables F-1 and F-2.

F.1.1. Feathering vs. free-wheeling below a cut-in speed of 3.5 m/s

Researchers tested the effect of feathering vs. free-wheeling below a cut-in speed of 3.5 m/s at the Fowler Ridge Wind Farm in Indiana, during the fall bat migration season in 2011 (15 July to 15 October) [72]. They reported a statistically-significant 36% decrease in bat fatalities with feathering compared to allowing turbines to free-wheel below cut-in speed, which was the normal operational procedure [72].

F.1.2. Feathering vs. free-wheeling below a cut-in speed of 4.0 m/s

A study to assess the effect of feathering vs. free-wheeling was conducted in 2007 at Summerview I Wind Facility in Alberta, Canada during the peak migration of hoary and silver-haired bats (1 August to 7 September) [126]. Control turbines had a manufacturer's cut-in speed of 4.0 m/s and were allowed to free-wheel below cut-in, whereas treatment turbines were feathered below 4.0 m/s. A statistically significant decrease in fatalities (i.e., approximate 58% reduction) was observed at feathered treatment turbines compared to turbines allowed to free-wheel [39], [126].

The effects of feathering vs. free-wheeling on bat collision risk were also examined in 2010 and 2011 at NedPower's Mount Storm Wind energy facility in West Virginia during bat migration (15 July to 13 October), yielding mixed results [137], [138]. In 2010, a 22-72% reduction in bat fatalities was observed when blades were manually feathered below the 4.0 m/s operational cut-in speed compared to control turbines that were allowed to free-wheel below cut-in, and these reductions were most apparent during the first half of the night (approximately five hours after sunset, 47 to 72% reduction; [137]). It is unclear, however, if these reductions were statistically significant at the 0.05 (5%) alpha level[12]. In 2011, feathering of the blades was automated for self-regulation during changing wind speeds [138]. Overall bat fatalities at feathered turbines were not significantly lower than at free-wheeling control turbines (approximate 9% reduction), potentially due to lack of statistical power (i.e., low numbers of bat fatalities were observed) [39], [138]. Further analysis of the Mount Storm data, indicated that when only nights during which feathering occurred were considered, bat fatalities were significantly reduced at feathered vs. control turbines [39], [137], [138].

F.2. Curtailment above Manufacturers' Cut-in Speeds

[12] Results were reported by the authors as significant at the 0.10 (10%) alpha level only.

The sections below provide detailed descriptions of several studies that have examined the effectiveness in reducing bat fatalities at wind energy facilities by implementing curtailment above manufacturers' cut-in speeds, as described in Section 4 of the Review. These studies are summarized in the sections below and in Tables F-1 and F-2.

F.2.1. Curtailment below wind speeds of 4.0 m/s

As of the date of this document, no studies have been conducted in Canada that evaluate the effectiveness of curtailing below 4.0 m/s. One study exists from an anonymous wind energy facility in the U.S. Pacific Southwest, although results were not statistically significant. At this project, cut-in speeds were raised from 3.0 m/s to 4.0 m/s with feathering for four hours nightly, from 2 August to 30 September 2012, under a randomized design [39]. A 20.1% reduction in bat fatalities was measured when curtailment was employed at 4.0 m/s vs. controls, but the finding was not statistically significant.

F.2.2. Curtailment below wind speeds of 4.5 m/s

At an anonymous wind energy facility in the Midwestern U.S., cut-in speeds were raised at treatment turbines from 3.5 m/s to 4.5 m/s nightly from 1 August to 1 October 2010, with feathering [39]. The randomized study demonstrated an approximate 47% decrease in fatalities that was statistically significant.

Researchers tested the effect of raising cut-in speed to 4.5 m/s with feathering compared to normal operations (3.5 m/s cut-in speed and turbines allowed to free-wheel) at the Fowler Ridge Wind Farm in Indiana from 15 July to 15 October 2011 [72]. They observed an approximate 58% decrease in bat fatalities at the treatment turbines that was statistically significant [72].

An experiment was conducted in 2011 at the Wolfe Island wind energy facility in Ontario, in which a 4.5 m/s cut-in speed with feathering was applied to experimental turbines from sunset to sunrise (15 July to 30 September), compared to a 3.2 m/s cut-in speed for controls [127]. Bat fatalities were reduced by approximately 48% at the experimental turbines [39], [127]; however, statistical analyses were not conducted because few fatalities were observed and consequently these results should be interpreted with caution.

An experiment was conducted in 2014 at the Raleigh Wind Energy Center in Ontario, in which a 4.5 m/s cut-in speed with feathering was applied to experimental turbines from sunset to sunrise (15 July to 30 September), compared to a 3.5 m/s cut-in speed for controls [142]. Bat fatalities were reduced by approximately 77% at the experimental turbines which was statistically significant [142].

F.2.3. Curtailment below wind speeds of 5.0 m/s

As of the date of this document, no studies have been conducted in Canada that evaluate the effectiveness of curtailing below 5.0 m/s. Six studies exist from projects in the U.S., of which three included results that were statistically significant.

In 2008 and 2009, curtailment experiments were conducted at Casselman Wind Power Project in Pennsylvania to examine the effectiveness of a 5.0 m/s cut-in speed with feathering [128]. Control turbines were managed using a 3.5 m/s cut-in speed with feathering. Treatments were randomly assigned, and results indicated an approximate 87% fatality reduction when turbines were curtailed in 2008 and an approximate 68% reduction in 2009 [128]. These reductions, however, represent combined results from turbines curtailed at 5.0 m/s and 6.5 m/s[13]. Statistical analyses were not conducted to specifically assess the effect of employing a 5.0 m/s curtailment strategy in comparison to controls. The reported reductions therefore do not clearly reflect the effectiveness of using a 5.0 m/s strategy and should be interpreted with caution.

The effect of increasing cut-in speed to 5.0 m/s with feathering was tested at the Fowler Ridge Wind Farm in Indiana during the fall bat migration season, 1 August to 15 October 2010 [129]. Treatment and control (3.5 m/s cut-in speed) turbines were randomly assigned. Results demonstrated a statistically significant, 50% reduction in bat fatalities at treatment turbines.

Turbines at the Criterion Wind Project in Maryland were curtailed from 15 July to 15 October 2012 to assess the effectiveness of feathering blades below a cut-in speed of 5.0 m/s [134]. No control turbines were assigned; instead, effectiveness of curtailment was determined by comparing bat fatality rates of treatment turbines for the study period (2012) with bat fatality rates at the same turbines during the previous year when no operational curtailment was implemented (2011). Estimated bat fatality rates at the treatment turbines were approximately 62% lower than in the previous year and this difference was statistically significant. These results should be interpreted with caution, however, as they are based on the assumption that other factors that could affect bat fatality from wind turbines (e.g., wind speeds, temperatures, migration passage, local bat activity) were similar across years.

An anonymous wind energy facility in the U.S. Pacific Southwest conducted experiments with 5.0 m/s cut-in speeds with feathering from 2 August to 30 September 2012 [39]. Two treatments were employed: increasing cut-in speed for four hours starting at sunset, and increasing cut-in speed for the entire night. Control turbines operated with the manufacturer's cut-in speed of 3.0 m/s. Findings demonstrated a 34.5% reduction in bat fatalities when cut-in speed was increased for four hours per night, and a 32.6% reduction in bat fatalities when cut-in speed was increased for the entire night. These findings were not statistically significant, potentially as a result of the relatively low numbers of fatalities observed during the study resulting in low statistical power, and should be interpreted with caution.

Researchers also tested the effectiveness of employing a 5.0 m/s cut-in speed with feathering at the Pinnacle Wind Farm in West Virginia between 15 July and 30 September 2013 [139]. Control turbines had an operational cut-in speed of 3.0 m/s with blade feathering. A statistically significant 54.4% reduction in bat fatalities occurred at turbines operating under the increased cut-in speed.

F.2.4. Curtailment below wind speeds of 5.5 m/s

A study examining the effect of feathering below a 5.5 m/s cut-in speed was conducted at Summerview I Wind Facility in Alberta between 1 August and 7 September 2007, during the peak migration of hoary and silver-haired bats [126]. Control turbines had a manufacturer's cut-in speed of

[13] Statistical analyses were performed on combined data from turbines curtailed at 5.0 m/s and 6.5 m/s (i.e., fatality estimates from the two increased cut-in speed treatments were statistically similar). Results from the pooled data analysis indicated that bat fatalities were significantly reduced at turbines operated under increased cut-in speeds compared to controls (combined reduction of 82% and 72% for 2008 and 2009, respectively) [128].

4.0 m/s, whereas treatment turbines had cut-in speeds raised to 5.5 m/s. Significantly fewer bat fatalities (i.e., approximate 60% reduction) were observed at treatment turbines compared to control turbines [126].

An anonymous wind energy facility in the Midwestern U.S. conducted experiments to assess the effect of increasing cut-in speed to 5.5 m/s with feathering compared to control turbines operating with 3.5 m/s cut-in speeds from 1 August to 1 October 2010 [39]. Results indicated an approximate 72% decrease in bat fatalities that was statistically significant. Fatality estimates were primarily based on observed eastern red bat, hoary bat, and silver-haired bat carcasses.

An experiment was conducted at Wolfe Island wind energy facility in Ontario from 15 July to 30 September 2011 to assess the efficacy of using a 5.5 m/s curtailment strategy with feathering [127]. A reduction in fatalities of approximately 60% was observed compared to controls (i.e., 4.0 m/s) [39], [127]. Statistical analyses were not conducted because few fatalities were observed and consequently these results should be interpreted with caution [39].

Researchers tested the effect of raising cut-in speed to 5.5 m/s with feathering compared to normal operations (3.5 m/s cut-in speed and turbines allowed to free-wheel) at the Fowler Ridge Wind Farm in Indiana from 15 July to 15 October 2011. They found that there was a statistically significant, 73.3% decrease in bat fatalities at turbines with raised cut-in speeds [72].

An experiment was conducted in 2012 at the Enbridge Ontario Wind Power Project in Ontario, in which a 5.5 m/s cut-in speed with feathering was applied to experimental turbines from sunset to sunrise (15 July to 30 September), compared to a 3.5 m/s cut-in speed for controls [143], [144]. Bat fatalities were reduced by approximately 62% at the experimental turbines which was statistically significant [143], [144].

An experiment was conducted in 2013 at the Talbot Wind Farm in Ontario, in which a 5.5 m/s cut-in speed with feathering was applied to experimental turbines from sunset to sunrise (15 July to 30 September), compared to a 3.5 m/s cut-in speed for controls [145]. Bat fatalities were reduced by approximately 96% at the experimental turbines which was statistically significant [145].

F.2.5. Curtailment below wind speeds of 6.0 m/s

As of the date of this document, no studies have been conducted in Canada that evaluate the effectiveness of curtailing below 6.0 m/s. Three studies exist from projects in the U.S., of which two included results that were statistically significant.

An anonymous wind energy facility in the U.S. Pacific Southwest Region tested the effectiveness of employing a 6.0 m/s cut-in speed with feathering compared to controls (i.e., cut-in speed of 3.0 m/s) from 2 August to 30 September 2012 [39]. A 38% reduction in bat fatalities was measured at turbines with the raised cut-in speed compared to control turbines. These findings were not statistically significant, likely as a result of the low numbers of fatalities observed during the study and subsequent low statistical power.

Researchers conducted a study at the Sheffield Wind Facility in Vermont from 3 June to 30 September of 2012 and 2013 to examine the effectiveness of a 6.0 m/s cut-in speed with feathering [140], [334]. Treatments included control turbines (fully operational at cut-in speed of 4.0 m/s) and turbines curtailed up to a cut-in speed of 6.0 m/s when the ambient air temperature was ≥9.5 °C (49 °F) and feathered. Compared to the control turbines, bat fatalities were reduced by approximately 60% in 2012 (statistically significant) and by 30% in 2013 (non-significant) [140].

F.2.6. Curtailment below wind speeds of 6.5 m/s

As of the date of this document, no studies have been conducted in Canada that evaluate the effectiveness of curtailing below 6.5 m/s. Four studies exist from projects in the U.S., of which two included results that were statistically significant.

In 2008 and 2009, curtailment experiments were conducted at Casselman Wind Power Project in Pennsylvania to examine the effectiveness of a 6.5 m/s cut-in speed with feathering [128]. Control turbines were managed using a 3.5 m/s cut-in speed with feathering. There was an approximate 74% fatality reduction compared to controls when turbines were curtailed in 2008 and an approximate 76% reduction in 2009 [128]. Statistical analyses were not conducted to assess the effect of employing a 6.5 m/s curtailment strategy in comparison to controls[14], so this result should be interpreted with caution.

Researchers examined the effect of employing a 6.5 m/s cut-in speed with feathering at the Fowler Ridge Wind Farm in Indiana from 1 August to 7 September 2010 [129]. A statistically significant 78% reduction in bat fatalities at a cut-in speed of 6.5 m/s was observed, compared to controls (3.5 m/s cut-in speed).

Researchers tested the effect on bat fatalities associated with feathering below a cut-in speed of 6.5 m/s at the Pinnacle Wind Farm in West Virginia between 15 July and 30 September 2013 [139]. A 76.1% statistically significant fatality reduction was observed at treatment turbines compared to control turbines with a cut-in speed of 3.0 m/s with feathering.

In addition to comparisons to control turbines, several studies have compared the effects of employing a 6.5 m/s to a 5.0 m/s cut-in speed on bat fatality rates, with mixed results. Two studies examined differences in fatality rates between using a 6.5 m/s cut-in speed and a 5.0 m/s cut-in speed and found no significant difference between the two treatments [128], [139]. Alternatively, one study observed a 57% reduction in bat fatality rates between turbines operated at 6.5 m/s compared to 5.0 m/s that was statistically significant [129].

F.2.7. Curtailment below wind speeds of 6.9 m/s

Researchers conducted a study at Beech Ridge Wind Project in West Virginia between 1 April and 15 November 2012 [141] to examine the effectiveness of a 6.9 m/s cut-in speed. Curtailment consisted of altering cut-in speeds to 6.9 m/s with feathering from one half hour before sunset to one-quarter hour after sunrise throughout the study period. The project was required to implement the curtailment on all operational turbines and subsequently no turbines were treated as controls during the study period [141]. Bat fatality rates were assessed in comparison to measured bat fatality rates at other regional and local wind energy facilities (i.e., within eastern North America, the northeastern region of

[14] Analyses were performed on pooled data from turbines curtailed at 5.0 m/s and 6.5 m/s (i.e., fatality estimates from the two increased cut-in speed treatments were statistically similar). Results from the pooled data analysis indicated that bat fatalities were significantly reduced at turbines operated under increased cut-in speeds compared to controls (combined reduction of 82% and 72% for 2008 and 2009, respectively) [128].

the U.S., and West Virginia). The Beech Ridge Wind Project annual fatality estimate with curtailment was below the mean annual fatality rates observed at other projects in eastern North America (approximate 75% reduction) and in West Virginia specifically (approximate 89% reduction); however, no statistical tests were performed on these data.

Table F-1 Curtailment Study Conditions

Project Identifier	Project Name and Location	Geographic Region	Cut-in Speeds Implemented	Dates of Study Period	Curtailment Timing	Additional Information (Temperature Threshold, Curtailment Trigger)	Turbines			Reference(s)
							Type, Capacity	Tower Height	Rotor Diameter	
1	Summerview I Wind Facility, Alberta	Agriculture	4.0[a] and 5.5 m/s	1 August – 7 September 2007	All day (24 hours a day)	N/A	Vestas V80, 1.8 MW	65 m	80 m	[126]
2	Casselman Wind Project, Pennsylvania	Deciduous forest, grassland	5.0 and 6.5 m/s	27 July – 9 October 2008 26 July – 8 October 2009	Half an hour before sunset to half an hour after sunrise	• Curtailment implemented when wind speeds were between 3.5 and 6.5 m/s	GE SLE, 1.5 MW	80 m	77 m	[128]
3	NedPower Mount Storm Wind Energy Facility, West Virginia	Deciduous forest, grassland	4.0 m/s[a]	15 July – 13 October 2010	5 hours after sunset 5 hours prior to sunrise	N/A	Gamesa G80, 2 MW	78 m	80 m	[137]
4	Anonymous project, Midwestern Region U.S.	Agriculture	4.5 and 5.5 m/s	1 August – 1 October 2010	1 hour before sunset to 1 hour after sunrise	N/A	Make/model not disclosed, 1.65 MW	80 m	82 m	[39]
5	Fowler Ridge, Indiana	Agriculture	5.0 and 6.5 m/s	1 August – 15 October 2010	Sunset to sunrise	N/A	GE SLE, 1.5 MW; Vestas V82, 1.65 MW; Clipper C96, 2.5 MW	80 m (all)	77 m; 82 m; 96 m	[129]

Table F-1 Curtailment Study Conditions

Project Identifier	Project Name and Location	Geographic Region	Cut-in Speeds Implemented	Dates of Study Period	Curtailment Timing	Additional Information (Temperature Threshold, Curtailment Trigger)	Turbines			Reference(s)
							Type, Capacity	Tower Height	Rotor Diameter	
6	Wolfe Island Wind Facility, Ontario	Agriculture	4.5 and 5.5 m/s	15 July – 30 September 2011	Sunset to sunrise	N/A	Siemens Mark II, 2.3 MW	80 m	93 m	[127]
7	Fowler Ridge, Indiana	Agriculture	3.5[a], 4.5, and 5.5 m/s	15 July – 15 October 2011	Sunset to sunrise	N/A	GE SLE, 1.5 MW; Vestas V82, 1.65 MW; Clipper C96, 2.5 MW	80 m (all)	77 m; 82 m; 96 m	[72]
8	NedPower Mount Storm Wind Energy Facility, West Virginia	Deciduous forest, grassland	4.0 m/s[a]	16 July – 13 October 2011	Automated with wind speeds	• Stop spin when wind speeds drop below 4.0 m/s for 6 minutes • Start spin when wind speeds rise above 4.0 m/s for 6 minutes	Gamesa G 80, 2 MW	78 m	80 m	[138]
9	Beech Ridge Wind Farm, West Virginia	Deciduous forest	6.9 m/s	1 April – 15 November 2012	All night	N/A	GE, 1.5 MW	80 m	77 m	[141]
10	Criterion Wind Farm, Maryland	Deciduous forest	5.0 m/s	15 July – 15 October 2012	All night	N/A	Clipper Liberty, 2.5 MW	80 m	93 m	[134]

Table F-1 Curtailment Study Conditions

Project Identifier	Project Name and Location	Geographic Region	Cut-in Speeds Implemented	Dates of Study Period	Curtailment Timing	Additional Information (Temperature Threshold, Curtailment Trigger)	Turbines			Reference(s)
							Type, Capacity	Tower Height	Rotor Diameter	
11	Sheffield Wind Facility, Vermont	Deciduous forest, mountain ridges	6.0 m/s	3 June – 30 September 2012 3 June – 30 September 2013	Half an hour before sunset to sunrise	• >9.5° C • Stop spin when wind speeds drop below 6.0 m/s for 5 minutes Start spin when wind speeds rise above 6.0 m/s for 10 minutes	Clipper Liberty, 2.5 MW	80 m	93 m	[140]
12	Anonymous project, Pacific Southwest Region U.S.	Sagebrush	4.0, 5.0, and 6.0 m/s	2 August – 30 September 2012	4 hours from sunset (4.0, 5.0, and 6.0 m/s) All night (a second treatment of 5.0 m/s)	N/A	Make/model not disclosed, 2.3 MW	80 m	101 m	[39]
13	Pinnacle Wind Farm, West Virginia	Deciduous forest	5.0 and 6.5 m/s	15 July – 30 September 2013	Sunset to sunrise	N/A	Mitsubishi, 2.4 MW	80 m	95 m	[139]
14	Raleigh Wind Energy Center, Ontario	Agriculture	4.5 m/s	15 July – 30 September 2014	Sunset to sunrise	N/A	GE, 1.5 MW	80 m	77 m	[142]

Table F-1 Curtailment Study Conditions

Project Identifier	Project Name and Location	Geographic Region	Cut-in Speeds Implemented	Dates of Study Period	Curtailment Timing	Additional Information (Temperature Threshold, Curtailment Trigger)	Turbines			Reference(s)
							Type, Capacity	Tower Height	Rotor Diameter	
15	Enbridge Ontario Wind Power Project, Ontario	Agriculture	5.5 m/s	15 July – 30 September 2012	Sunset to sunrise	N/A	Vestas V82, 1.65 MW	80 m	82 m	[143], [144]
16	Talbot Wind Farm, Ontario	Agriculture	5.5 m/s	15 July – 30 September 2013	Sunset to sunrise	N/A	Siemens SWT-2.3-101, 2.3 MW	80 m	101 m	[145]

[a] Manufacturers' default cut-in speed. Experiments at this speed involved feathering of the blades.

Table F-2 Curtailment Study Findings

Project Identifier	Study Cut-In Speed	Percent fatality reduction (CI if reported[a])	Number of Test Turbines	Estimator	Mean bat fatalities/ turbine/study period (CI if reported[a])	Control		Statistically Significant (compared to controls)?	Statistical Analysis
						Type[b]	Cut-in Speed		
7	3.5 m/s	36.3 (12.4-53.8[c])	126	Shoenfeld-Erickson [84]	Not reported	S	3.5 m/s	Yes	Chi-square analysis; P = 0.005
12	4.0 m/s	20.1	40	Not identified	Not reported	S	3.0 m/s	No	Chi-square analysis; P > 0.05
3		47-72	24	Erickson [335]	0.05 (0.03-0.07)	S	4.0 m/s	Yes	Poisson model; P < 0.01
		22-50			0.09 (0.06-0.12)			Yes	Poisson model; P < 0.01
8		9.3[d2]	24	Erickson [335]	6.45	S	4.0 m/s	No	Chi-square analysis; P > 0.1
1		57	6	Baerwald [336]	8.1 (5.0-11.2)	S	4.0 m/s	Yes	ANOVA; P = 0.006
4	4.5 m/s	47	12	Not identified	Not reported	S	3.5 m/s	Yes	Poisson model; P = 0.01
6		48[d1]	14	Ontario MNRF adapted [88]	2.73	S	3.2 m/s	N/A	N/A

Table F-2 Curtailment Study Findings

Project Identifier	Study Cut-In Speed	Percent fatality reduction (CI if reported[a])	Number of Test Turbines	Estimator	Mean bat fatalities/ turbine/study period (CI if reported[a])	Control		Statistically Significant (compared to controls)?	Statistical Analysis
						Type[b]	Cut-in Speed		
7	4.5 m/s	58 (38.5-69.8[c])	126	Shoenfeld-Erickson [84]	Not reported	S	3.5 m/s	Yes	Chi-square analysis; $P < 0.001$
14		77	15	Ontario MNRF adapted [88]	5.3	S	3.5 m/s	Yes	Non-overlapping CI
12	5.0 m/s	35.3	40	Not identified	Not reported	S	3.0 m/s	No	Chi-square analysis; $P > 0.05$
		32.6			Not reported			No	Chi-square analysis; $P > 0.05$
5		50 (37.3-60.6[c])	27	Shoenfeld-Erickson [84]	7 (7.0-9.1[c])	S	3.5 m/s	Yes	Poisson model; Non-overlapping CI
2		87[d1]	12	Not identified	0.27 (0.07-1.05)	S	3.5 m/s	N/A[e]	Chi-square analysis; $P = 0.004$[e]
		68[d1]	12		0.73 (0.34-1.56)			N/A[e]	Chi-square analysis; $P = 0.005$[e]
13		54 (17.7-74.7)	12	Huso [70]	0.533 (0.259-0.957)	S	3.0 m/s	Yes	Poisson model; $P = 0.009$

Table F-2 Curtailment Study Findings

Project Identifier	Study Cut-In Speed	Percent fatality reduction (CI if reported[a])	Number of Test Turbines	Estimator	Mean bat fatalities/ turbine/study period (CI if reported[a])	Control		Statistically Significant (compared to controls)?	Statistical Analysis
						Type[b]	Cut-in Speed		
10	5.0 m/s	62	14	Huso [70]	1.94 (0.85-3.28[d])	PR	4.0 m/s	Yes	Poisson model; Non-overlapping CI
4	5.5 m/s	72	12	Not identified	Not reported	S	3.5 m/s	Yes	Poisson model; P < 0.001
1		60	15	Baerwald [336]	7.6 (4.7-10.5)	S	4.0 m/s	Yes	ANOVA; P = 0.006
6		60	14	Ontario MNRF adapted [88]	2.08	S	3.2 m/s	N/A	N/A
7		73.3 (60-82.5[c])	126	Shoenfeld-Erickson [84]	Not reported	S	3.5 m/s	Yes	Chi-square analysis; P < 0.001
15		62	17	Ontario MNRF adapted [88]	5.6	S	3.5 m/s	Yes	Chi-square analysis; P < 0.05
16		96	12	Ontario MNRF adapted [88]	Not reported	S	3.5 m/s	Yes	Not explicit, but assumed P < 0.05
12	6.0 m/s	38.1	40	Not identified	Not reported	S	3.0 m/s	No	Chi-square analysis; P > 0.05

Table F-2 Curtailment Study Findings

Project Identifier	Study Cut-In Speed	Percent fatality reduction (CI if reported[a])	Number of Test Turbines	Estimator	Mean bat fatalities/turbine/study period (CI if reported[a])	Control		Statistically Significant (compared to controls)?	Statistical Analysis
						Type[b]	Cut-in Speed		
11	6.0 m/s	60 (29-79)	16	Huso [70]	1 (0.60-1.80)	S	4.0 m/s	Yes	Poisson model; $P < 0.01$
		30			0.25 (0.09-0.73)			No	Poisson model; $P = 0.54$
5	6.5 m/s	78 (10-84.9[c])	27	Shoenfeld-Erickson [84]	3 (1.8-4.2[c])	S	3.5 m/s	Yes	Poisson model; Non-overlapping CI
2		74	12	Not identified	0.53 (0.20-1.42)	S	3.5 m/s	N/A[e]	Chi-square analysis; $P = 0.004$[e]
		76	12		0.55 (0.23-1.31)			N/A[e]	Chi-square analysis; $P = 0.005$[e]
13		76	12	Huso [70]	0.32 (0.157-0.637)	S	3.0 m/s	Yes	Poisson model; $P < 0.001$
9	6.9 m/s	73-89[f]	67	Shoenfeld-Erickson [84]	Not reported[g]	CP	3.5 m/s	N/A	N/A

[a] 95% Confidence Interval (CI) unless otherwise reported.
[b] S = study used a control group(s) during the study period; PR = study used data from previous years to compare results; CP = study used data from local comparative projects.
[c] 90% CI.
[d] Results were 1) back-calculated from bat fatality rates or 2) provided by a third-party source (i.e., [39]).

[e] Includes two studies for which only pooled results from multiple curtailment thresholds (5.0 m/s, 6.5 m/s) were analysed and found to be significant; unclear if individual threshold produced significant results [128].
[f] Based on comparisons with local and regional projects.
[g] Reported as bat fatalities/turbine/year = 3.04 (95% CI = 1.89-7.44)

APPENDIX G – EMERGING TECHNOLOGIES

Considerations for assessing the utility of emerging technologies may include biological uncertainties or questions about compatibility with current industry processes, as summarized in Table G-1.

Table G-1 Considerations for assessing the utility of Emerging Technologies

Biological	Technical	
• Are there uncertainties pertaining to bat behavioural response (e.g., does the technology have the potential to act as an attractant)? • Has the technology been shown to affect bat behaviour, bat fatality, or both? • For which species is the technology most likely to be effective? • Is the technology likely to affect non-target species (e.g., domestic or wildlife)? • Can the technology serve dual purposes (e.g. monitor or deter birds and bats)?	• Will the technology require a power source? If Yes: – How will this affect current power systems? – Will new supply sources (e.g., ports, wires) be necessary? – Is the technology Canadian Standards Association (CSA) compliant and certified? • How will the technology be addressed in OEM service supplier agreements? • Is the technology compatible with current warranty and maintenance contracts? • Does the technology require mounting (nacelle, blade or tower), and if so, how will this affect structural integrity (e.g. from drilling)? • If blade mounted, – How will the technology affect blade characteristics (i.e. airfoil shape) and performance (e.g., lift, rotation)? – Has the technology undergone loads validation testing? – If a module weighs more than pre-defined thresholds, have the load implications of the deterrent been reviewed by the certifying agency? – Is the technology compatible with vortex generators or other performance improvement modifications?	• Will the technology impact regular maintenance (e.g., blade cleaning)? • If relevant, is integration with current Supervisory Control and Data Acquisition (SCADA) systems feasible? – How will the technology be integrated with the SCADA system (time signatures, communication with controller)?* – How will software updates to SCADA systems affect the technology? – Will integration with the SCADA system pose any security threat? • If nacelle-mounted, – Will it be mounted to current mounting structures? • How will the technology be maintained (e.g. wire replacements, cleaning)? • Is the technology likely to perform better under certain environmental conditions or in specific regions? • Are there safety concerns? • Are there potential disturbance issues to abutting properties? • What are the potential costs (or cost savings as compared to employing other minimization strategies such as curtailment)? •

*Note that integrating after-market signals into SCADA systems is complex, will likely require OEM support, and will need to comply with warranty and maintenance requirements. This may not always be practical.

G.1. Deterrents

Emerging deterrent technologies are summarized below according to three categories: ultrasonic acoustic deterrents, tower surface coatings, and lighting. Testing of several of the new technologies is currently funded under the U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE)[15] program, and information pertaining to these studies is primarily based on direct communication with the product development teams and reflects the current status of their respective evaluation processes. It should be noted that bat deterrent devices for which information is available have been evaluated in the U.S. and thus may not yet explicitly address all potential Canadian conditions.

G.1.1. Ultrasonic Acoustic Deterrents – Published Results

G.1.1.1. Effectiveness – Bat Behaviour

Several laboratory and field studies have demonstrated that acoustic devices can impact bat behaviour and space use. At the University of Maryland, a prototype eight-speaker deterrent (AT800 portable ultrasonic amplifier and transducer unit) that emitted continuous white noise (frequencies ranging from 12.5 to 112.5 kHz at approximately 100 dB sound pressure level [SPL] per speaker) appeared to deter big brown bats from landing in a flight room testing area containing the device (1.7%, trial vs. 22.4 %, control areas) [157]. In follow up feeding trials, bats were less successful at taking a tethered mealworm when the device was emitting sound nearby, although it is unclear if this was a result of bat inability to locate the prey item or bat avoidance of the area [157]. Bats in both trials also flew through the area with the device significantly less when it was emitting sound than when it was silent. These laboratory results provided preliminary evidence that broadcasting broadband sounds may hold promise for deterring bats away from the source of the sound.

For subsequent field testing, researchers modified the device described above [157] to broadcast a slightly narrower band of continuous ultrasonic white noise at an increased SPL (20 to 80 kHz; approximately 120 dB SPL) [169], [170]. Field tests were conducted at pond sites in California and Oregon from July to August 2006, and at several additional pond sites in California, Oregon, and Arizona from August to September 2007. Findings from both years demonstrated a significant reduction in bat activity rates (i.e., bat passes/hour) when the device was broadcasting compared to controls [169], [170] with an approximate 50% reduction in bat activity in the first year of the study [169] and 90-98% reduction in bat activity in the second year [170]. The ultrasound signals broadcast during the study only affected bats up to approximately 12 to 15 m from the source, however, representing less than one-half the length of most turbine rotors [170] and a small proportion of the spatial volume of the RSA.

Field tests were also conducted to assess the efficacy of commercially-available ultrasonic pest deterrents (Model EX900-A, frequency range 26 to 74 kHz, 105 dB SPL) in July 2009 at two ponds in West Virginia [171]. Findings demonstrated that when the ultrasonic deterrents were deployed, the mean number of nightly bat passes within the range (approximately 30 m) of the deterrents was significantly lower than at control sites (approximate 17% reduction). An ultrasonic acoustic device (16 transducers, continuous sound 20 to 100 kHz range, ≥65 dB SPL in a waterproof box) was also tested at a plantation in Hawaii in October 2013 [164]. Findings demonstrated a significant reduction

[15] Funded under the U.S. DOE, Office of EERE program, to advance the technical and commercial readiness of bat impact mitigation and minimization technologies (DE-FOA-0001181).

in mean bat passes at trees located near deterrents (approximately 20 m) to control sites without deterrents (approximate 85% reduction). Bat activity was higher at one of the deterrent sites than at controls, however, likely due to habitat factors (i.e., proximity to a tree row), underscoring the influence of landscape factors in determining deterrent effectiveness [164].

One published study that examined the use of an acoustic deterrent at an operational wind facility was available for review. The study tested an ultrasonic deterrent device with three emitter arrays that broadcast pulsed, randomized broadband ultrasonic emissions in various frequency ranges (20 to 80 kHz; 119 dB SPL) at four turbines at a wind energy facility in New York in August 2007; two turbines were fitted with ultrasonic acoustic deterrents and two served as controls [168]. Two 10-day experimental trials were conducted, wherein comparable portions of the RSZs of one treatment turbine and one control turbine were monitored with IR cameras. In the first trial, findings demonstrated a significant difference between bat activity at control and treatment turbines (131 bats in the treatment group and 244 bats in the control group), but the second trial did not indicate a statistical difference in bat activity between treatment and control turbines. The researchers acknowledged that the ultrasonic deterrent used in the trials may not have been able to broadcast at a sufficient dB level to affect bats outside of the RSZ [168].

G.1.1.2. Effectiveness – Fatalities

One published study was available for review that examined the effects of an acoustic deterrent on bat fatality rates at an operational wind facility. An ultrasonic acoustic deterrent (16 transducers, continuous sound 20 to 100 kHz in a waterproof box) was tested in the summer and fall of 2009 and 2010 on wind turbines at the Locust Ridge Wind Project in Pennsylvania [150]. Thirteen turbines were used as controls and 15 turbines were fitted with a deterrent device. The effectiveness of the deterrent was determined by daily carcass searches for the length of the study periods. Results were mixed between the two years. In 2009, an estimated 21 to 51% fewer bats were observed as fatalities at treatment turbines compared to controls, and this effect was statistically significant. In 2010, however, there was no statistical difference in the number of fatalities recorded at treatment vs. control turbines (approximate 9% reduction) [150]. The researchers suggested that their mixed results may have been a function of the rapid attenuation of sound produced by the deterrents which likely did not reach the entire RSZ [150].

G.1.2. Ultrasonic Acoustic Deterrents – Current Research

Based on findings reported over the last decade that demonstrate success in deterring bats through the use of acoustic transmissions, several new acoustic-deterrent technologies have been developed and are undergoing evaluation (see Section 4 of the Review). Results from previous deterrent research showed that ultrasound attenuates rapidly due to atmospheric absorption and that this attenuation of sound limits coverage area; therefore, much focus has been placed on increasing coverage area in order to deter bats before they enter the RSZ.

The acoustic deterrent devices summarized here are mounted on turbine towers, nacelles or blades, with some incorporating components that are installed within the nacelle. Several of the devices have electronic components and require a power source. Because the sound generated by these devices is in the ultrasonic range and thus inaudible to humans, disturbance is unlikely, however, potential effects on other taxa (e.g. insects, birds, other mammals) have not been studied. Overall, acoustic deterrent methods have undergone more testing than have other types of deterrents and have shown the most promise for reducing bat fatalities at operational wind farms. Several devices may be commercially available within the next few years (1 to 3 years), pending further evaluation of effectiveness and compatibility with turbine operations.

G.1.2.1. Nacelle / Tower-mounted ultrasonic transducer[15]

Bat Conservation International, with the support of the Bats & Wind Energy Cooperative (BWEC), and in collaboration with Iberdrola Renewables (now Avangrid Renewables), the U.S. Geological Survey, and various engineering partners (currently Renewable NRG Systems; previously Deaton Engineering, Inc.; Binary Acoustic Technology, LLC) has been studying the suitability and effectiveness of ultrasonic acoustic deterrents of various designs for use at wind energy facilities. Multiple studies on various acoustic devices have been conducted since 2006 [337] (see Section 4 of the Review), and BCI is currently assessing a newly designed ultrasonic acoustic deterrent for functionality and effectiveness. The deterrent is a modified version of an earlier device which demonstrably reduced bat activity in laboratory and field testing, but generated mixed results with respect to reducing fatalities at an operational wind energy facility [150].

The acoustic deterrent is designed to be mounted to a nacelle and uses piezoelectric transducers to generate sound. Unlike previous devices, which were more unidirectional in sound-broadcast [150], this transducer provides a greater spread of the signal and is more omnidirectional to increase area coverage. To further increase coverage, the frequency range on the newer device is narrower so will allow for increased intensity and a subsequent longer range, with the goal of reaching beyond the RSA at a decibel level that is suitable for deterring bats. The signal will encompass the range of characteristic frequencies from approximately 20-55 kHz used by all bat species in Canada. The newer device is also being designed to be more field robust than older designs and is expected to limit overheating, water ingress, and other environmental factors, which have been shown to render some acoustic deterrents inoperable in earlier studies [150].

The developers are evaluating the new ultrasonic acoustic deterrent to determine the best placement and orientation to ensure compatibility and functionality, including determining how well the ultrasonic acoustic deterrent interfaces with turbine software (i.e., SCADA) and can be controlled remotely by operators. A functionality assessment was conducted at the Locust Ridge Wind Project in Pennsylvania in 2009 and 2010 [150], and finalized units were tested at operational facilities in Texas, Ontario, and the Midwestern U.S. in 2017 for effectiveness in reducing bat fatalities. Focal species were those most commonly recorded in Ontario and Eastern Canada including eastern red bat, hoary bat, and silver-haired bat, as well as species impacted by WNS, including tri-colored bat, little brown bat and northern myotis. Findings from the 2017 studies have not yet been published.

G.1.2.2. “Smart Blade Systems” - Blade-mounted ultrasonic transmitters[15, 16]

Frontier Wind, in collaboration with Pattern Energy, the U.S. Forest Service, WEST Inc., and INCE Cert. is designing and evaluating a blade-mounted ultrasonic transmitter for reducing bat collisions at wind energy facilities [338].

The system under evaluation consists of 10 transmitters on each of the blades, starting at 5 m from the tip, in a linear array that is held onto the blade with a main wire harness that runs into the hub of the turbine where the control box will be mounted. Target frequencies of the system undergoing testing will range from 20-60 kHz to fit within the range of peak frequencies of local bat species in California (silver-haired bat; hoary bat; Brazilian free-tailed bat; and big brown bat), but frequency ranges can be customized based on project-specific community conditions. The blade-mounted system is expected to mitigate for attenuation effects [339] (see Section 4 of the Review) by providing a larger coverage area, because it is on a moving structure and is peripherally located to more effectively reach the entire RSA, unlike nacelle- or turbine-mounted units. The transmitters are designed to be resistant to atmospheric and turbine operating conditions. Simulations and preliminary laboratory tests have shown that the transmitters do not affect the performance of the blade or interfere with the lighting protection system and can be effectively mounted within manufacturer defined locations on the blade where ancillary devices can be installed.

Installation of the transmitters at the Hatchet Ridge Wind Project in California for field testing was completed in fall of 2016, and two years of fatality monitoring is currently underway to evaluate the effectiveness of the device for reducing bat fatalities.

G.1.2.3. Blade-mounted, wind-powered ultrasonic whistle[15]

University of Massachusetts Amherst in collaboration with Texas A&M University is developing and testing a blade-mounted ultrasonic whistle, with additional support from the National Science Foundation (NSF) Integrative Graduate Education and Research Traineeship (IGERT) program, and MA Clean Energy Center.

The whistle is designed based on bat larynx morphology, will modulate within a broadband ultrasonic range (25 to 55 kHz), and will not require power or electricity because sound will be mechanically generated when wind passes through the moving whistle [340]. The aim of the design is to overcome shortcomings of current acoustic devices that are nacelle-mounted and thus do not provide coverage of a turbine’s RSA, and to avoid the potential environmental issues associated with exposed electronic systems. Whistles will be mounted along the blade and its developers are examining potential methods for mounting on and/or integration with vortex generators at the blade tips, to further extend sound coverage beyond the RSA. The unit is expected to function in wind speeds of up to 6 m/s and blade speeds of up to approximately 42 m/s (lower bounds will be identified during testing). Evaluation of the ultrasonic whistle will occur in multiple stages and the design has yet to be finalized.

[16] The development of this device is also being funded by a California Energy Commission grant.

G.1.2.4. High-velocity, compressor-powered air jet[15]

Renewables in collaboration with Invenergy, Texas Christian University (TCU), Shoener Environmental Inc., and Skalski Statistical Services is developing and testing a high-velocity, compressor-powered air jet ultrasonic acoustic deterrent. The air jet creates ultrasound in the range of 20-60 kHz. The compressors are contained inside the turbine to ensure that no electronics are exposed to environmental stressors and to minimize any audible noise, and proper operation of the device is easily verified with standard instrumentation in order to reduce monitoring and maintenance requirements. According to the developers, the ultrasonic deterrents do not increase the overall turbine noise level in the far-field at International Electrotechnical Commission (IEC) noise certification distances. The primary objectives for the development of this device include; creating a 10-fold larger impact area than previous ultrasonic devices (i.e., typical transducer-based systems, see Section 4 of the Review), covering a large range of frequencies through broadband ultrasonic emission, offering an easily mountable design, reducing costs compared to curtailment solutions, providing simple hardware mechanisms with easy operation and maintenance, and being compatible with multiple turbine OEM models.

The air jet has been tested on bats in the wild at non-turbine sites (ponds) and has reduced bat activity (as indicated by thermal IR monitoring data) near the ultrasonic acoustic deterrent. Sound emitters that approximated the amplitude and frequency of the GE device at were tested with captive bats in the laboratory at TCU. Results indicated that the treatments affected the bats behavioural responses (e.g., foraging ability) however the unnatural, confined setting of the laboratory flight room made it difficult to infer the deterrent's effectiveness in the field. The system has undergone field testing as a nacelle-mounted device, nacelle- and tower-mounted device, and tower-mounted device at an operational wind energy facility in the Midwestern U.S. Researchers have reported a statistically significant reduction of bat fatalities of approximately 30% each year for the deterrent-treated turbines compared to untreated control turbines, and an approximate 56% reduction in carcasses when eastern red bats were excluded from the data.

As of 2016, the researchers were continuing to explore tower mounting options for the emitter and testing with pulsed, as opposed to constant, sound. The pulsed configuration is designed to improve effectiveness by increasing the number of deterrent emitters installed on the turbines and improve effectiveness for eastern red bats.

G.1.3. Tower Surface Coatings[15]

Based on the hypothesis that bats misperceive the smooth surfaces of wind turbine towers to be water (see Section 4 of the Review), a new technology using experimental coatings is being developed to deter bats from closely approaching and touching turbine tower surfaces. Surface coatings currently under development are designed to be applied to turbine towers either as a retrofit or during manufacturing. Surface coatings must adhere to Canadian Aviation Regulations (CARs) Standard 621 which currently require that turbines are painted specific white or off-white shades [180]. If shown to be effective, the application of surface coatings could serve as a low/moderate cost deterrent alternative that is less likely to diminish in performance over time as a result of environmental stressors (i.e., as compared to electronic deterrents) and is believed to be highly unlikely to be incompatible with turbine operations. The technology is in the very early stages of development, however, and is based on acoustic experiments, observations of bats at operational wind turbines, and flight room experiments with wild-caught bats. Surface technologies have not yet been tested at an operational wind energy facility for effectiveness. If proven effective, these coatings may serve as stand-alone deterrents or may be applied concurrently with other deterrents or minimization methods. As currently conceived, tower coatings are unlikely to deter bats from entering the RSZ; however, by removing an attractant feature from the tower, they are expected to reduce overall bat activity in the airspace close to turbines.

Researchers at TCU, with the support of NextEra Energy Resources, LLC, have been studying bat attraction to wind turbines and methods for reducing turbine attractiveness. Preliminary observations by the research team have confirmed that individual bats will make multiple passes and contacts with smooth manufactured surfaces (including vertical surfaces); suggesting that bats may spend increased time in or near RSAs if they are behaving similarly towards turbine tower surfaces. The goal of the research is to develop one or more texturized surface coatings that bats do not closely approach and that can be applied to operational wind turbine towers as a retrofit option. Texturizing methods are economically feasible to produce and apply, will not affect performance of the turbine, and can be retrofitted to existing turbines. The coatings under development are designed to equal or outlast the life-span of the turbine (i.e., approximately 30 years) with components that will be ultraviolet (UV) resistant and able to withstand environmental conditions (e.g., snow, ice, rain) without degrading or breaking down.

The research team has tested bat responses to surfaces treated with appliques or one of three paint textures (i.e., different texture grades) created with paint additives. A series of behavioural studies on wild-caught bats was conducted under controlled flight room conditions to determine bat responses to each of the experimental surfaces as well as to smooth surfaces representing typical turbine paint conditions. Trials consisted of treatment of a curved metal piece to simulate a turbine tower and high speed camera observations of various behavioural responses (e.g., foraging, drinking attempts). Foraging and drinking behaviours were exhibited by bats at the smooth surfaces and preliminary analyses indicated that that the texturized paint surfaces were visited less frequently by bats. Appliques, however, were determined to be ineffective for deterring bat approaches. Species tested included eastern red bat, evening bat, and Brazilian free-tailed bat. Further flight room testing with a single commercially-produced texturized paint coating was conducted in 2016, followed by ongoing testing of the finalized coatings on a larger scale at Wolf Ridge Wind Farm to assess effectiveness in reducing bat activity near turbines at an operational facility.

G.1.4. Lighting

Based on current knowledge about the ability of bats to process visual cues (see Section 4 of the Review), testing has recently begun to assess bat responses to UV light and explore the potential for developing deterrent methods incorporating UV light [179], [185]. It has been suggested that the application of UV methods might affect the ability of tree-roosting bats to differentiate between the silhouettes of trees and wind turbines [110], [136], [183], [341], with the expectation that providing visible UV light to bats could allow them to better discern between the two landscape features from long distances [185] and thus better avoid turbines. However, research on bat response to UV lighting is still in the very early stages and has produced variable results for different species, locations, and ambient conditions [185]. Studies thus far have not included bat species native to Canada, and potential effects on other taxa are unclear. Full-scale testing of UV has also not yet been conducted on wind turbines, and more research will be necessary in this area to evaluate the potential effectiveness of using UV lighting as an avoidance and minimization tool. If shown to be effective, devices incorporating lighting deterrents will likely entail tower- or nacelle-mounting and will require a power source.

Collaborative research by University of Hawaii at Hilo, the U.S. Geological Survey (USGS), and Bat Research and Consulting examined the ability of several species of insectivorous bats to see reflected UV light under dim lighting conditions in the laboratory [179], and how one bat species (Hawaiian hoary bat [*Lasiurus cinereus semotus*]) responded to dim flickering UV light under natural conditions [185]. Results showed that in the laboratory, all seven bat species that were examined could perceive low-intensity UV illumination (with a peak wavelength of 365 nm, at 1 microwatt reflected power), a light level that would be barely visible to humans and most birds but may be representative of nocturnal ambient conditions experienced by bats [179], [185]. Species tested included three Myotis species (little brown myotis; cave myotis [*Myotis velifer*]; and long-legged myotis) as well as California leaf-nosed bat (*Macrotus californicus*), big brown bat, Townsend's big-eared bat and Brazilian free-tailed bat.

Further testing was conducted to identify how dim-light conditions affect bat behaviour under natural conditions. By illuminating treatment trees with a dim, flickering light (duty cycle 0.1 to 5 s; 1 microwatt power; 20 m radius around treatment trees), researchers were able to show that Hawaiian hoary bat echolocation activity was reduced by approximately 44% under UV lighting conditions, despite the fact that insect activity increased at these treatment sites. Although behavioural findings based on thermal videography were mixed, there were also indications that bats at both near-range ($\leq$ 25 m) and mid-range (> 25 m to $\leq$ 50 m) distances may have moved away from illuminated trees.

A preliminary field test was conducted on one turbine in fall 2015 to assess the feasibility of using UV emitters at wind energy facilities. UV emitters were mounted both atop and below the nacelle of the turbine and remained functional for the 10 nights of operation during which the assessment occurred. Insect aggregations were not observed around the lights. Large-scale testing for effectiveness for deterring bats is expected to begin in summer 2017 at an operational wind energy facility in Pennsylvania currently experiencing relatively high fatalities, pending funding.

G.1.5. Deterrents Summary

Overview summaries and status of emerging deterrent technologies are provided in Table G-2. Note that details pertaining to acoustic range are currently being evaluated and are therefore not reported, with the acknowledgement that attenuation and range are limiting factors for the effectiveness of these devices. It should also be noted that any deterrent technology must be determined to not adversely affect the operational efficiencies or cause issues with manufacturer's warranties for that particular technology before it could be considered for deployment."

Table G-2 Emerging Deterrent Technologies: Overview and Status (as of July 2016)

Deterrent	Preliminary Findings (effects on bats)	Project Time Schedule			Commercial Readiness[a]					Considerations		
		Lab Testing[b]	Field Testing[c]	Region / State[d]	1	2	3	4	5	Species[e]	Environmental Exposure	Other Considerations
Nacelle / Tower –mounted Ultrasonic Transducer	Preliminary findings for earlier, similar designs have demonstrated localized bat avoidance response, and indicate hoary and silver-haired bat fatality reductions in some years.	Fall 2015	Spring – Fall 2016[c2]; Summer – Fall 2017[c3]	Northeastern US[f], Texas, Midwestern US, and Ontraio[g]	X	X	X	X	X	• Species potentially affected in field testing: LABO, LACI, LANO. • Current system is configured for species in the 20 to 55 kHz range.	• Power unit mounted to nacelle and locked in a weather-proof case.	• Designed to be more field robust than previous models. • Omnidirectional to have a wider area of sound coverage.

Table G-2 Emerging Deterrent Technologies: Overview and Status (as of July 2016)

Deterrent	Preliminary Findings (effects on bats)	Project Time Schedule			Commercial Readiness[a]					Considerations		
		Lab Testing[b]	Field Testing[c]	Region / State[d]	1	2	3	4	5	Species[e]	Environmental Exposure	Other Considerations
"Smart Blade Systems" - Blade-mounted Ultrasonic Transmitters	Preliminary results unavailable. Two years of field testing to begin September 2016.	Spring 2016	September 2016[c2]; 2016 – 2017[c3]	Pacific Coast (California)	X	X		X		• Species potentially affected in field testing: LANO, LACI, TABR, EPFU. • Current system is configured for species in the 20-60 kHz range, but can be custom-designed for species in higher ranges.	• Transmitters are sealed. • Control box will be protected via mounting in the hub of the turbine. • System highly resistant to water and dust.	• Current design operates at temperatures above -20 °C; however, developers report that the unit is customizable for colder environments. • The device is currently designed as a retrofit, but future testing is expected to explore potential integration into the design of the turbine blades (i.e., embedded in blades) which could further reduce any friction effects.

Table G-2 Emerging Deterrent Technologies: Overview and Status (as of July 2016)

Deterrent	Preliminary Findings (effects on bats)	Project Time Schedule			Commercial Readiness[a]					Considerations		
		Lab Testing[b]	Field Testing[c]	Region/State[d]	1	2	3	4	5	Species[e]	Environmental Exposure	Other Considerations
Blade-mounted, Wind-powered Ultrasonic Whistle	Currently undergoing lab testing for functionality and lab response of Mexican free-tailed bats (*Tadarida brasiliensis mexicana)*. Preliminary findings indicate that using flexible membranes may mimic bat frequency modulations.	Summer 2016[b1,b2]	Spring-Summer 2017[c2]	Northeastern US (Massachusetts)	X	X				• Species potentially affected in field testing: LACI, LANO, LABO. • Species tested in lab: MYLU, PESU, EPFU, TABM. • Current system is configured for emitting concurrent 40, 60, 80 and 120 kHz signals.	• Whistle in early stages of development and environmental factors (temperature effects and particulate matter exclusion) will be addressed.	• Will not require power or electricity. • Small, can be mounted along length of blade.

Table G-2 Emerging Deterrent Technologies: Overview and Status (as of July 2016)

Deterrent	Preliminary Findings (effects on bats)	Project Time Schedule			Commercial Readiness[a]					Considerations		
		Lab Testing[b]	Field Testing[c]	Region/State[d]	1	2	3	4	5	Species[e]	Environmental Exposure	Other Considerations
High-velocity, Compressor-powered Air Jet	Effective for reducing bat activity based on ground studies near ponds; Demonstrated effectiveness of approximately 30% reduction in bat fatalities at operating wind energy facility.	2015[b2]	Summer – Fall; 2013 – 2016[c2]	Midwestern US	X	X	X	X	X	• Species potentially affected in field testing: LABO, LACI, LANO. • Species testing in lab: LABO, NYHU, TABR. • Current system is configured for species in the 20-60 kHz range.	• Power unit mounted inside tower, limiting exposure to environment.	• Components are expected to be easy to maintain and verify using standard equipment.

Table G-2 Emerging Deterrent Technologies: Overview and Status (as of July 2016)

Deterrent	Preliminary Findings (effects on bats)	Project Time Schedule			Commercial Readiness[a]					Considerations		
		Lab Testing[b]	Field Testing[c]	Region/State[d]	1	2	3	4	5	Species[e]	Environmental Exposure	Other Considerations
Texturized Surface Coatings	In lab tests, texturized surfaces were visited less frequently than smooth surfaces.	July – September 2014 and 2015[b2]; Summer 2016	Summer – Fall 2016[c2]; Summer – Fall 2017[c3]	Southwest (Texas)	X		X			• Species tested in lab: LABO, NYHU, TABR. • Species potentially affected in field testing: LABO, LACI, LANO, NYHU, TABR, PESU.	• Paint or applique on turbine tower will be exposed to and will be designed to withstand environmental conditions (UV, snow, ice, and rain resistant).	• Cost-effective, especially when applied prior to construction. • Most likely to be used in combination with other avoidance and minimization measures. • No electronics or power source required. • Will not affect performance of turbine. • Potential to be effective within the distance at which bats echolocate (e.g., up to approximately 30 m for eastern red bat). • Follow CARs Standard 621, in which turbines are required to be painted white or off-white [180].

Table G-2 Emerging Deterrent Technologies: Overview and Status (as of July 2016)

Deterrent	Preliminary Findings (effects on bats)	Project Time Schedule			Commercial Readiness[a]					Considerations		
		Lab Testing[b]	Field Testing[c]	Region/State[d]	1	2	3	4	5	Species[e]	Environmental Exposure	Other Considerations
UV Lighting	Hawaiian hoary bat echolocation activity reduced at non-turbine sites by approximately 44% under dim, low-wavelength UV lighting conditions.	2014	2015 [c1]	Hawaii[h]	X	X	X			• Species tested in lab: MYLU, MYVE, MYVO, MACA, EPFU, COTO, TABR. • Species tested in preliminary field tests: LACS.	• Preliminary testing demonstrated functionality under varied weather conditions (10-day test period).	• Bat and insect response varied as a factor of moon illumination in field testing. • Surface reflectivity and other factors need to be studied at turbine testing sites. • Potential effects on other species unknown (may require animal care review). • CARs Standard 621 requires that lighting on wind turbines minimize fatalities of birds and interference with nighttime astronomical study [180].

[a] The ranking of commercial readiness is determined based on the stage of development of the projects. These rankings are described as follows: 1) conceptual design; 2) ground testing (for unit performance); 3) lab testing with captive bats; 4) field testing on turbines; and 5) some statistical evidence of effectiveness (e.g., reduction in bat fatalities).

[b] Lab testing is defined by two categories: b1) Testing of components and/or system; and b2) Captive bat response testing.

[c] Field testing is defined by three possible categories: c1) Ground testing of components and/or system; c2) Preliminary field testing on operational/test turbine(s); and c3) Field testing at an operational wind energy facility with fatality monitoring.

[d] Region where field testing has been or is scheduled to be conducted.

[e] LABO = eastern red bat; LACI = hoary bat; LANO = silver-haired bat; TABR = Brazilian free-tailed bat; EPFU = big brown bat; MYLU = little brown myotis; PESU = tri-colored bat; TABM = Mexican free-tailed bat; NYHU = evening bat; MYVE = cave myotis; MYVO = long-legged myotis; MACA = California leaf-nosed bat; COTO = Townsend's big-eared bat; LACS = Hawaiian hoary bat.

[f] Field testing of early units was conducted at an operational wind energy facility in Pennsylvania in 2009 and 2010 [150].

[g] Post-construction monitoring studies conducted in 2017; note that Table is current to July 2016 and therefore does not include 2017 results.

[h] No field testing on turbines published to date.

G.2. Integrated Detection-Deterrent and Detection-Avoidance Systems

G.2.1. Acoustic and Thermographic Offshore Monitoring (ATOM™) system

Acoustic and Thermographic Offshore Monitoring (ATOM™) is a system developed for offshore and onshore wind energy facilities that combines thermal IR imaging with acoustic and ultrasound sensors to monitor bird and bat abundance, flight height, direction, and speed [218], [342]. The system is designed to provide information about movement and behaviour of individual birds and bats for use in targeted curtailment of wind turbines. Normandeau Associates Inc., with support from the U.S. Department of Interior, Bureau of Ocean Energy Management, and Cornell Lab of Ornithology designed the ATOM™ system, which has been effective for gathering data on bird and bat abundance, flight height, speed, and direction of flight [218], [342]. Information gathered by the system may facilitate prediction of collision risk to inform automated curtailment regimes; however, further evaluation of the effectiveness in predicting bat activity and reducing fatality risk is still warranted. Limitations to the system include a requirement for cellular connectivity for the video and acoustic components to transmit near real-time data, and potentially greater efficiency in detecting birds from bats. In addition, flight altitude has only been measured when a passing bat is within 75 m of an IR unit due to limitations in both sampling area and image resolution [342].

G.2.2. ReBat® and TIMR℠

The ReBat® (acoustic recording and identification system) and TIMR℠ (collision-risk system) systems, developed by Normandeau Associates Inc. have undergone initial testing with support from Electric Power Research Institute (EPRI) and We Energies. The ReBat® bat-focused monitoring system is designed to be mounted on turbine nacelles or MET towers, and when coupled with the TIMR℠ data system and a facility's existing SCADA system, triggers automated turbine curtailment under defined high-risk conditions (i.e., based on bat activity and weather parameters). Testing of the TIMR℠ system was initiated at Blue Sky Green Field Wind Farm in Wisconsin in 2012, but the results have not been published.

G.2.3. DTBat®

The DTBat® system was developed by Liquen Consultoria Ambiental, S.L. in Spain. The system uses ultrasonic audio recording devices on wind turbines to detect bat passes and links to the turbine control system (e.g., SCADA) to trigger operational curtailment. The system's Stop Control Module is designed to curtail or restart turbines as a function of real-time bat activity and includes an option to incorporate real-time environmental conditions in its curtailment algorithms (e.g., wind speed and temperature; [343]). The system has an approximate 7-second delay between the time when bat activity thresholds are met and output of the curtailment trigger signal. Preliminary tests of the monitoring components of the DTBat® system were recently conducted at a wind farm in Switzerland; however, the Stop Control Module was not employed at that time [344]. The expected performance of the DTBat® stop program algorithm was instead evaluated based on simulation models that incorporated empirical bat activity data recorded by the DTBat® microphones; the models varied by threshold definition (i.e., single bat pass vs. double bat pass), stop duration of the turbine (i.e., 40-60 min) and other conditions. Results predicted an approximate 90% reduction in the proportion of passing bats at risk of collision, and an 8 to 10% energy production loss, during the simulation period (8 August to 31 October 2014) when turbines were curtailed for 60 min after being triggered by a single bat pass [344]. These results were similar to those observed using a fixed environmental stop program that did not incorporate bat activity data in its curtailment algorithms at the same wind energy facility (i.e., curtailment algorithm included only environmental parameters; [344]).

G.2.4. Chirotech©

The Chirotech© system, developed by the French company Biotope, was initially designed to predict risk and curtail turbines based on bat activity from baseline ultrasound recordings, wind speed, fatality monitoring data, and meteorological data. More recently, the Chirotech© system was integrated with thermal imaging cameras (Decan®) mounted on the turbine towers to monitor bats as they fly close to the turbine blades, with the goal of better predicting and subsequently minimizing risk through targeted curtailment. The integrated system underwent preliminary testing at two land-based wind farms in Ontario, with unpublished results from the system developer indicating a 60-97% reduction in fatality and less than 2% loss of production [345]. The system was also tested for two years on turbines in northeastern France with preliminary results indicating a significant decrease in fatalities and power output loss below 1% of annual production [346]. These results are promising but it was acknowledged that further research is required to determine fatality reduction and production costs at other wind farm locations [346]. In 2013, Chirotech© was pending industrial certification, but the current status of this certification is unknown.

G.2.5. MERLIN™ SCADA

DeTect, Inc. developed the MERLIN™ radar technology system that can be integrated with SCADA systems to allow for automated mitigation during operations [347], [348]. MERLIN™ monitoring is based on Doppler radar technology (i.e., horizontally- and vertically-oriented marine radar units) and data processing software designed to identify flying birds and bats, and has been installed at several terrestrial and offshore facilities worldwide (e.g., U.S., Belgium, The Netherlands, Poland, and Turkey). The system has been integrated with SCADA at multiple onshore facilities in Texas (e.g., Gulf Wind I, Penascal) to monitor and curtail select turbines under high fatality risk conditions as determined by bird and bat radar activity, weather and visibility conditions, and other sensor data inputs. The system is also used at operational airfields with the aim of reducing bird strikes. Data regarding the effectiveness of this system for reducing avian or bat fatality at wind energy facilities have not been published. General limitations associated with radar monitoring include reduced capabilities under high moisture conditions, cost, and potential issues with noise and clutter, particularly for offshore sites [202], [348]. Radar also cannot typically differentiate between bird and bat targets.

G.2.6. Summary

Table G-3 summarizes the status, benefits, and limitation of several integrated detection avoidance systems that are commercially available or in development and testing phases. Note that the list of technologies presented represents a sample of available systems and is not comprehensive.

Table G-3 Integrated Systems Technology: Overview and Status

Technology	Benefits	Limitations	Considerations		
			Example System(s)	Commercial Availability	Environmental Conditions
Integrated IR/Acoustic Systems	• Efficient at identifying combined bird and bat abundance, flight trajectory, and speed.	• May be more efficient at detecting birds than bats. • Primarily used at offshore installations. • Some systems have not yet been integrated with SCADA for testing.	ATOM™ Chirotech©	Yes, some are currently available but evaluation of effectiveness is still needed.	Ultrasound sensors can be negatively affected by harsh offshore conditions.
Integrated Acoustic Systems	• Effectiveness in reducing bat fatality documented in limited studies, more research needed.	• Acoustic detectors only effective when bats are emitting calls.	TIMR℠ DTBat®	Yes, several systems commercially available	Bats may not echolocate in large open areas, including during migration. Therefore, acoustic monitoring alone may be insufficient for offshore installations or within other open areas.
Integrated Radar Systems	• Provide vertical- and horizontal distribution data in real-time.	• High radar monitoring and data processing costs. • Cannot typically distinguish between avian and bat targets.	MERLIN™	Yes, some systems commercially available	Reduced capabilities under high moisture conditions. Issues with data noise and clutter, particularly in offshore environments.

APPENDIX H – COMPENSATION AND OFFSET OPTIONS

H.1. Forest Management Options

H.1.1. Logging Practices in Forests

The extent of logging, or selective logging, in forests has the potential to influence the quality of forest habitat for bats. A study in Ontario late-successional boreal forests found that under low (70% retention), medium (50% retention) and high (30% retention) intensity tree harvesting practices, the number of bats using these habitats differed [349]. Low intensity harvesting practices had no impact on the number of bats using these sites, medium intensity had some negative impacts, and high intensity had large negative impacts on bats. Therefore, the greater an area is logged and trees removed, the less suitable the habitat for bat species in the boreal forests.

Forest thinning (selective removal of trees to improve growth/health of remaining trees) can enhance habitat for bats [350]. Thinning of pine stands was found to provide more foraging habitat for bats in South Carolina [351]. Bat habitat selection in forest patches of varied tree densities due to different harvest practices was studied in boreal mixed-wood forests in Alberta [352]. The harvest practices assessed ranged from no management (i.e., intact forest) to clear-cut regimes. Smaller and more manoeuvrable bat species (e.g., myotis sp.) were less affected by changes in tree density than larger less manoeuvrable species (e.g., silver-haired bat). Specifically, little brown myotis selected edges of clear-cut areas, northern myotis selected intact forest, and silver-haired bat selected clear-cut areas for foraging. In West Virginia, northern myotis were selected intact forest stands, with a relatively closed canopy [353]. Overall findings suggest that forest management that creates a variety of forest patches with different tree densities is likely to create habitat for more bat species than a system with less diverse harvesting styles.

Forest fragmentation (i.e., breaking apart intact forest into patches or fragments) and corresponding increases in forested edge habitat also appears to influence the quality of bat habitat. In Ontario, several species of bats were found to be more active at the edges of forests, including northern myotis, little brown myotis, hoary bat, silver-haired bat, and big brown bat [354]. The depth of edge influence (i.e., the extent of change in activity with distance from an edge) for all species was approximately 40 m into both forest and field habitats [354]. These findings suggest that there are potential minimum habitat patch size criteria for these bat species, but they have not yet been defined. In Ontario, a study found that forest fragmentation had different impacts on different bat species [288]. Fragmentation had positive effects on myotis sp. and eastern red bat habitat use, but silver-haired bat and tri-colored bat were less likely to use fragmented habitats than unfragmented habitats. A study in South Carolina also found that openings and gaps within mature forests, as well as the presence of large open areas (regeneration sites, wildlife openings), provided suitable foraging and roosting habitat for bats [355]. Although studies are limited, findings indicate that forest fragmenting activities such as patch cutting or clear cutting may increase habitat suitability for some species. The application of different logging practices can be applied to surrounding habitats of wind energy facilities to help minimize potential attractions of bats to the project areas, or may be used to enhance habitat in other areas as a habitat enhancement compensation measure.

H.1.2. Tree Species Composition

The tree species that comprise forest habitats appear to be important for bats. In Saskatchewan, bats were found to be more active in aspen (*Populus sp.*)/white spruce (*Picea glauca*) mixed forests than in aspen or jack-pine (*Pinus banksiana*) forests [356]. In Alberta, bats were found to prefer dying or newly dead aspen trees with heart rot for roosting [357]. Bat response to forest composition is also likely species-specific with certain bat species showing habitat preferences for tree species (e.g., western red bat showing preference for cottonwood, walnut, oak, willow, and sycamore; fringed bat showing preference for ponderosa pine). General forest types may also be important (e.g., eastern red bat and mixed hardwood forests, long-eared myotis and coniferous forests, Keen's long-eared bat and old-growth rainforests, and eastern small-footed myotis and deciduous or coniferous forests; see Section 2 of the Review and Appendix A). Further research is necessary to determine if managing tree species composition can be an effective tool for wind energy facility bat habitat compensation.

H.1.3. Canopy Height

Forest canopy height may influence the quality of forest habitat for bat species, but few studies to assess this potential relationship have been published. In Saskatchewan, there was no influence of canopy height on overall bat activity, but bat activity below the canopy was observed to peak towards sunset, and was found to be uniform throughout the night within and above the canopy [356]. In Alberta, bats were found to prefer tall (average 22 m) trees and low leaf cover in old growth forests [357]. Further research is necessary to determine if managing canopy height can be an effective tool for wind energy facility bat habitat compensation.

H.1.4. Agricultural Practices within Forested Habitats

Forest fragmentation through the opening of areas for agriculture practices can provide for additional forest edge habitat and foraging areas that appear to influence the quality of bat habitats. The depth of forest edge influence for bat species was approximately 40 m into both forest and field habitats [354]. This suggests that there are potential minimum size criteria for agricultural areas, intermingled with forests, to provide for foraging habitats for bat species.

Forest fragmentation through the opening of areas for agriculture practices can provide for additional forest edge habitat and foraging areas that appear to influence the quality of bat habitats. The depth of forest edge influence for bat species was approximately 40 m into both forest and field habitats [354]. This suggests that there are potential minimum size criteria for agricultural areas, intermingled with forests, to provide for foraging habitats for bat species.

Land sparing agricultural practices create landscapes where agricultural production occurs in a yield-maximizing manner using less land and sparing land for nature [358]. Land sharing agricultural practices create landscapes where lower-intensity agriculture and biodiversity largely co-exist with little untouched land. If species using both land sparing and sharing practices are present, then land sparing is best. Where intermediate species (those using landscapes under both land sparing and land sharing regimes) are present, the optimal solution is a combination of land sharing and sparing in the landscape, which is likely the most real-world landscapes case for land management.

Agricultural practices in orchards and woodlots may influence the use of these habitats by bats. Bats preferred chestnut (*Castanea sp.*) orchards that have been thinned, allowing space for bats to fly around and forage in the orchards [359]. Conversely, abandoned forests become thick and dense making them difficult for bats to forage within. Agricultural practices of orchards that provide for maneuverability of bats and use as foraging areas may provide for additional habitats for these species. It is currently unclear if agriculture practices that maintain bat habitats can be applied to surrounding habitats of wind energy facilities to minimize potential attractions of bats to the project areas.

H.2. Captive Bat Program Options

The CWHC *National Plan to Manage White Nose Syndrome in Bats in Canada* [254] identifies actions to determine the feasibility and role of captive management for species of conservation concern including translocation, temporary captivity, propagation, and cryopreservation. Captive programs have also been used in the U.S. to reduce threats of WNS [360]. Captive programs limit the spread of the disease, often with the goal of protecting threatened or endangered bat species [361]. Captive breeding programs are typically used to support wild bat populations and are not intended to replace other conservation initiatives [362]. In general, bats have complex requirements that are challenging to sustain in captivity.

The feasibility of short and long-term captive programs for six bat species under threat of WNS was addressed in a workshop in Missouri in 2010 [363]. Individual bat species were classified based on the extent to which they had been included in captive programs; Table H-1 lists species for which captive programs had been implemented [363], qualifies the demonstrated success of these programs, and identifies program limitations that were experienced.

Table H-1 Summary of Captive Programs for Canadian Bat Species

Bat Species	Captive Programs[a]	Demonstrated Success (Breeding Programs Only[b])	Limitations
Big Brown Bat	Long-term, extensive, breed, hibernate	Strong	None reported
California Myotis	None reported	None reported	None reported
Eastern Red Bat	Long-term, extensive, birth	Moderate	None reported
Eastern Small-footed Myotis	Limited, hold	Moderate	Low population
Fringed Bat	None reported	None reported	None reported
Hoary Bat	Long-term, extensive, hold	Moderate	None reported
Keen's Long-eared Bat	None reported	None reported	None reported
Little Brown Myotis	Long-term, extensive, hibernate	Weak	Low survivorship
Long-eared Myotis	None reported	None reported	None reported
Long-legged Myotis	None reported	None reported	None reported
Northern Myotis	Short-term, extensive, hold	Moderate	Low survivorship
Pallid Bat	Long-term, extensive, breed, hibernate	Strong	None reported
Silver-haired Bat	Long-term, extensive, hold	Moderate	None reported

Bat Species	Captive Programs[a]	Demonstrated Success (Breeding Programs Only[b])	Limitations
Spotted Bat	None reported	None reported	None reported
Townsend's Big-eared Bat	None reported	None reported	None reported
Tri-colored Bat	Long-term, extensive, hold	Moderate	Low population
Western Red Bat	None reported	None reported	None reported
Western Small-footed Myotis	Short-term, limited	Weak	None reported
Yuma Myotis	None reported	None reported	None reported

[a] Long-term; individuals have been successfully held in captivity for >1 month.
Short-term; individuals have been successfully held in captivity for <1 month.
Hold; individuals have been successfully held during reproductively active periods.
Birth; individuals were already pregnant and gave birth to live young in captivity.
Breed; individuals bred in captivity.
Limited; refers to the extent of experience with captive breeding.
Extensive; refers to the extent of experience with captive breeding.
Hibernate; individuals have been successfully held during hibernation periods.
[b] Strength of demonstrated results for increasing population size: Strong, successfully bred in captivity; Moderate, successfully held during breeding period and/or gave birth in captivity; Weak, no breeding observed in captivity.

The bat species that seem to be the most adaptable to captivity are generalists that glean for food (i.e., pick up prey from the ground or other surfaces) such as northern myotis [363]. In addition, non-colonial bat species (e.g., hoary bat), non-cave dependent species (e.g., big brown bat), and bats that come out of torpor frequently also appear to be more adaptable to captivity. The relative tolerance of individual bat species to human disturbance and handling is also important when considering captive programs. Little information is available on species-specific handling tolerance. More studies are required to assess how tolerance levels relate to the success of captivity programs.

The bat species that seem to be the most adaptable to captivity are generalists that glean for food (i.e., pick up prey from the ground or other surfaces) such as northern myotis [363]. In addition, non-colonial bat species (e.g., hoary bat), non-cave dependent species (e.g., big brown bat), and bats that come out of torpor frequently also appear to be more adaptable to captivity. The relative tolerance of individual bat species to human disturbance and handling is also important when considering captive programs. Little information is available on species-specific handling tolerance. More studies are required to assess how tolerance levels relate to the success of captivity programs.

In one captive breeding example, 70 Rodriguez fruit bats (*Pteropus rodricensis*) were captured in 1976 and held in a zoo facility; by 1992 there were nearly 200 bats in the captive breeding population [362]. Conversely, forty Virginia big-eared bats were collected and held in captivity over one winter (2009 to 2010) at the Smithsonian National Zoo [364]. Of these 40, only 11 have survived. This project was expensive (approximately $300,000) and less successful than anticipated because insectivorous bats are more difficult to raise in captivity than frugivorous bats. Many bats refused to eat worms from pans, were stressed from relocation, and were habituated to cave-specific temperatures and humidity which were difficult to replicate under captive conditions. Some of the bats also developed bacterial infections. Although fruit bat captive breeding programs have proven to be more successful than those for insectivorous bats [362], [364], they provide some confidence that similar programs can be developed for insectivorous bats as the knowledge base continues to grow.

In Canada, captive management has been specifically proposed as a conservation tool for bats [365]. An assessment was recently conducted by Wildlife Preservation Canada (WPC) to determine the utility of using captive breeding for five bat species (i.e., little brown myotis, northern myotis, eastern small-footed bat, tri-colored bat, and big brown bat) affected by the spread of WNS. It was concluded that due to the rarity of eastern small-footed and tri-colored bats it would be prohibitive to collect enough individuals to form a viable captive breeding population. Big brown bats appear to have fewer individuals with WNS so that captive breeding may not be warranted. Little brown myotis and northern myotis are potential candidates for captive breeding in Canada, but have been found to have low survivorship in captivity. Little brown myotis have been held in captivity for research only, not propagation, and it has been recommended that if this species is held over one winter it could increase survivability and provide some level of benefit to local populations upon release [360]. Experts are concerned about keeping this species in captivity for long periods of time due to the difficulty in maintaining natural behaviours, possible decrease in genetic diversity, and a belief that the low numbers that could be maintained in captivity would not buffer the population-level impacts of WNS. Similarly, eastern small-footed bats are recommended for holding over one winter, only. Northern myotis are generally not recommended for captivity [360].

The WPC also assessed the capabilities of 13 zoos and 29 wildlife rehabilitation facilities and found that none of which currently have the infrastructure required to house and care for bats long-term [365]. It was concluded that further studies of post-release survival of individuals from rehabilitation facilities, small-scale captive breeding experiments, and research on bat resistance to WNS are necessary to provide more information on how to re-introduce disease-resistant bats into the environment following captive breeding programs.

APPENDIX I – PROVINCIAL GUIDELINES

Table I-1 Provincial Guidelines for Pre-construction Monitoring & Assessment

	Province ("Yes" indicates that factor is specifically discussed in guidelines)							
	Alberta	British Columbia	Manitoba	New Brunswick	Nova Scotia	Ontario	Quebec	Saskatchewan[1]
Guidelines Consulted	Bat Mitigation Framework for Wind Power Development – Wildlife Land Use Guidelines (Alberta ESRD[2]) [132] Wildlife Directive for Alberta Wind Energy Projects (AEP[3]) [276]	Best Management Practices Guidelines for Bats in British Columbia Chapter 4: Wind Power Developments (British Columbia MOE[4]) [264]	Land Use Planning for Wind Energy Systems in Manitoba (Manitoba Intergovernmental Affairs) [366]	Pre-Construction Bat Survey Guidelines for Wind Farm Development in New Brunswick (New Brunswick Fish & Wildlife) [367]	Proponent's Guide to Wind Power Projects: Guide for preparing an Environmental Assessment Registration Document (Nova Scotia Environment) [368]	Bats and Bat Habitats: Guidelines for Wind Power Projects (Ontario MNR[5]) [88]	Protocole d'inventaires acoustiques de chiropteres dans le cadre de projets d'implantation d'éoliennes au Québec (Quebec DNRW[6])	Guidelines for Saskatchewan Wind Energy Projects (Saskatchewan MOE[4])
Status of Wind Energy-Bat Guidelines	Final (2013) Draft (as of March 2016)	Final (2016)	NA[7] (2009)	Final (2009)	NA[7] (2012)	Final (2011)	Final (2008)	Near Final (as of September 2016)
Definition of Areas with Potentially High Concentrations of Bats	Yes (based on acoustic monitoring)	Yes (based on acoustic monitoring)	Yes (based on habitat)	Yes (based on habitat)	Yes (based on habitat)	Yes (based on habitat)	Yes (based on habitat)	Yes (based on habitat)
Consult Existing Databases (Roosts, Bottlenecks)	Yes	Yes	Not specified	Yes	Yes	Yes	Yes	Not specified
Identify Suitable Habitat	Yes (maps, aerial photos)	Yes (include a 1 km buffer; potential aerial survey)	Not specified	Not specified	Not specified (Consult with Nova Scotia DNR[8])	Yes (mapped Ecological Land Classification)	Yes (maps and aerial photos)	Yes (mapped land cover types)
Acoustic Surveys	Yes	Yes	Not specified	Yes	Not specified (Consult with Nova Scotia DNR[8])	Yes	Yes	Yes, but vague
Duration of Acoustic Surveys	2 years between May and Sept); survey periods vary by region	2+ years "where possible"; additional surveys may be recommended based on year 1 data (e.g., presence of species at risk)	Not specified	1 year minimum (June, August-Sept); Additional sampling in areas with potentially high concentrations of bats (July, October)	Not specified (Consult with Nova Scotia DNR[8])	1-31 August	Minimum 1 breeding period (June-July) and 1 migration period (Aug-Oct)	Fall [369]
Siting Requirements with Respect to Roosts / Hibernacula	Yes (300 m from northern myotis roost sites and hibernacula)	Yes (Variable or site dependent)	Not specified	Not specified	Not specified	Yes (120 m from bat Significant Wildlife Habitat[9])	Not specified	Not specified
Additional Surveys	Yes (additional acoustic surveys, mist-netting, and hibernacula and other feature specific surveys)	Yes (Radar, mist-netting, radio-telemetry "as needed" if abandoned mines, caves, crevices, large tree cavities present)	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified
Consideration of Cumulative Effects	Yes	Yes	Not specified	Not specified	Yes (large [41-100 turbines] and very large [>101 turbines] projects)	Not specified	Not specified, but "requested"	Not specified

[1] Guidelines consulted were in draft form prior to September 2016; therefore, information presented in the table may not be current.
[2] Environment and Sustainable Resource Development.
[3] Alberta Environment and Parks.
[4] Ministry of Environment.
[5] Ministry of Natural Resources.

[6] Department of Natural Resources and Wildlife (*Ministère des Ressources naturelles et de la Faune*).
[7] Bat-focused guideline document for wind industry not available, but some recommendations provided in general provincial planning document for wind energy facilities. Provinces that are not listed do not appear to have developed bat-focused recommendations for the wind industry.
[8] Department of Natural Resources.
[9] Consult the Significant Wildlife Habitat (SWH) Technical Guide as provided in the appendices of the guidelines for defining SWH for bats [88].

Table I-2 Post-construction Monitoring & Mitigation Recommended by Provincial Guidelines. Specific Fatality Estimators Recommended are Available in Table 3-3.

	Province ("Yes" indicates that factor is specifically discussed in guidelines)							
	Alberta[1]	British Columbia	Manitoba	New Brunswick	Nova Scotia	Ontario	Quebec	Saskatchewan[2]
Guidelines Consulted	Bat Mitigation Framework for Wind Power Development – Wildlife Land Use Guidelines (Alberta ESRD[2]) [132] Wildlife Directive for Alberta Wind Energy Projects (AEP[3]) [276]	Best Management Practices Guidelines for Bats in British Columbia Chapter 4: Wind Power Developments (British Columbia MOE[4]) [264]	Land Use Planning for Wind Energy Systems in Manitoba (Manitoba Intergovernmental Affairs) [366]	Post-Construction Bat and Bird Mortality Survey Guidelines for Wind Farm Development in New Brunswick (New Brunswick Fish & Wildlife) [367]	Proponent's Guide to Wind Power Projects: Guide for preparing an Environmental Assessment Registration Document (Nova Scotia Environment) [368]	Bats and Bat Habitats: Guidelines for Wind Power Projects (Ontario MNR[5]) [88]	Protocole de suivi des mortalités d'oiseaux et de chiroptères dans le cadre de projects d'implantation d'éoliennes au Québec (Quebec MSDEACC[6])	Guidelines for Saskatchewan Wind Energy Projects (Saskatchewan MOE[4])
Status of Guidelines	Final (2013) Draft (2016)	Final (2016)	NA[7] (2009)	Final (2011)	NA[7] (2012)	Final (2011)	Final (2013)	Near Final (as of September 2016)
Duration of Fatality Monitoring	Minimum of 3 years after project is operational	3 years following commissioning and then every 5 years following	Developed through consultation with Federal (CEAA[8]) and provincial (MDOC[9]) regulatory agencies.	2 years	2+ years likely. Consult with Nova Scotia DNR[10] to establish monitoring standards	3 years	3 years following commissioning and then every 10 years following. Possibly additional monitoring depending on first 3 years of mortality events and consultation with agency	Not specified (protocol not available)
Number of Turbines Searched	Minimum of 20, randomly-selected turbines or $^{1}/_{3}$ of turbines, whichever is the larger number. Same must be sampled in subsequent years to infer patterns	≤ 10 turbines, 100%; > 10 turbines, 33-50%	Not specified	< 10 turbines, 100%; 11- 20 turbines, 10 turbines minimum; 21-40 turbines, 10 turbines or 33% of turbines (whichever is greater); > 40 turbines, 33% of turbines	Not specified	<10 turbines, 100%; >10 turbines, 30%	For the first 3 years: < 10 turbines, 100%; > 10 turbines, at least 40% with 10 turbines minimum. Following: to be determined based on results of the first 3 years	Not specified
Search Period	1 March to 30 October (unless high risk in winter months based on region – then surveys must be year-round)	15 March to 15 October	Not specified	31 March to 31 October	Seasons of elevated collision risk	1 May – 31 October	At minimum: breeding period (15 May to 31 July) and migration period (1 Aug to 17 Oct). Possibly more depending on yearly results and consultation with agency	Not specified
Search Radius	Area at least ½ the maximum height of the turbine (measured from tip of blade to the ground) or a radius of 50 m, whichever is larger	Minimum of 50 m or ½ maximum rotor height	Not specified	½ maximum rotor height	Not specified	50 m radius; rectangular, square, or circular plot	80 m x 80 m centered on turbine	Not specified

Table I-2 Post-construction Monitoring & Mitigation Recommended by Provincial Guidelines. Specific Fatality Estimators Recommended are Available in Table 3-3.

	Province ("Yes" indicates that factor is specifically discussed in guidelines)							
	Alberta[1]	British Columbia	Manitoba	New Brunswick	Nova Scotia	Ontario	Quebec	Saskatchewan[2]
Search Interval	Weekly	3-day minimum	Not specified	31 March to 31 May, 1 June to 31 July, 3 to 7 days; 1 August to 31 October, 3 days	Not specified (consult with Nova Scotia DNR[10])	Twice weekly (May to October)	During breeding (15 May to 31 July) and migration periods (1 Aug to 17 Oct): 3 days. Otherwise: 7 days	Not specified
Supporting Data (Additional Data to be Collected and Reported)	Not specified	Temperature, wind speed, wind direction, precipitation, cloud cover % and any significant weather prior to search	Not specified	Air temperature, wind speed/direction, precipitation (both pre- and post-construction)	Not specified	Weather conditions, wind speed, and precipitation	Meteorological conditions (wind, precipitation, temperature, fog)	Not specified
Additional Monitoring	If post-construction mitigation is required	Tissue sampling (genetic protocol provided, conditional but highly recommended for cryptic myotis species)	Not specified	Not specified	Not specified	Disturbance effects monitoring if ≤ 120 m of significant bat habitat	Not specified	Not specified
Fatality Threshold	> 8 migratory bats/turbine/year, or >500 site fatality estimate for 1 year	≥ 10 carcasses at any 1 turbine in 1 year, ≥ 7 bats/turbine/year fatality estimate, > 350 fatality estimate for 1 year, or fatality of any bat species at risk	Not specified	Significant bat fatality ("unexpected or unanticipated increased levels of mortality in comparison to other bat mortality surveys throughout North America")	Not specified	10 bats/turbine/year	Not specified. Consult with agency.	Specific finalized fatality threshold requirement currently under development Draft measures recommend: ≥ 4 bats/turbine/year, or ≥ 8 bats at any one turbine during a single monitoring survey
Operational Curtailment	Increase cut-in speed to 5.5 m/s. Low speed idle and feathering will also be considered as first-level mitigation.	Increase cut-in speed to 6 m/s, feathering and low-speed idling optional	Not specified	Selective operational shut-down of turbines (high bat activity, weather conditions)	Consult with Nova Scotia DNR[9]	Increase cut-in speed to 5.5 m/s and/or feather below cut-in	Not specified. Consult with agency.	Specific finalized operational curtailment requirements are not provided in the current guidelines Draft measures recommend: increase cut-in speed to 5.5 or 6.0 m/s and/or feather below cut-in
Timing of Operational Curtailment	1 August to 10 September; sunset to sunrise	Periods based on biologist input. If data unavailable, 15 March to 15 October; 30 min before sunset – 30 min after sunrise.	Not specified	Not specified	Not specified	15 July to 30 September; sunset to sunrise	Not specified. Consult with agency.	Specific finalized timing of operational curtailment currently under development Draft measures recommend: 15 July to 30 September; sunset to sunrise

Table I-2 Post-construction Monitoring & Mitigation Recommended by Provincial Guidelines. Specific Fatality Estimators Recommended are Available in Table 3-3.

	Province ("Yes" indicates that factor is specifically discussed in guidelines)							
	Alberta[1]	British Columbia	Manitoba	New Brunswick	Nova Scotia	Ontario	Quebec	Saskatchewan[2]
Duration of Curtailment	Not specified	Life of Project (not explicitly specified but implied)	Not specified	Not specified	Not specified	Life of Project	Not specified. Consult with agency.	Not specified
Fatality Monitoring During Curtailment	2 years during curtailment to assess effectiveness of mitigation strategy	3 years post-mitigation and every 5 years	Not specified	"Necessary" - duration not specified	Not specified	3 years during curtailment to assess effectiveness of mitigation strategy	Not specified. Consult with agency.	Not specified
Mitigation if Curtailment not Sufficiently Effective	Consult with ESRD- Wildlife Branch about possible mitigation and further monitoring - may include shut-off of turbines during peak migration	If any of the thresholds persist for 3 consecutive years, additional mitigation considered (including shutting down at night during periods of high bat fatalities)	Not specified	Further monitoring or studies may be required, including operational shut-down during periods of high activity or during specified weather conditions	Not specified	Develop in consultation with MNR	Not specified. Consult with agency.	May include modifying or changing equipment, adding deterrents, wildlife detection, or strike detector equipment to turbines and altering operating schedules
Other Operational Mitigation Recommended	Not specified	Yes (Use of deterrent devices encouraged if include a research component)	Not specified	Not specified	Not specified	Not specified	Not specified. Consult with agency.	Not specified

[1] Post-construction Wind Energy Protocol for Bats (http://aep.alberta.ca/fish-wildlife/wildlife-management/documents/PostCostructionBatProtocol-Jul-2015.pdf) was also consulted; however, because of inconsistencies between this protocol and the new directive it has not been included in the table.
[2] Guidelines consulted were in draft form prior to September 2016. Where appropriate, information differentiating between the draft and finalized guidelines is provided in the table.
Environment and Sustainable Resource Development.
[3] Alberta Environment and Parks.
[4] Ministry of Environment.
[5] Ministry of Natural Resources.
[6] Ministry of Sustainable Development, Environment, and Action against Climate Change (*Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques*).
[7] Bat-focused guideline document for wind industry not available, but some recommendations provided in general provincial planning document for wind energy facilities. Provinces that are not listed do not appear to have developed bat-focused recommendations for the wind industry.
[8] Canadian Environmental Assessment Agency.
[9] Manitoba Department of Conservation.
[10] Department of Natural Resources.

APPENDIX J – OPERATIONAL WIND ENERGY PROJECTS [AS OF 31 DECEMBER 2017]

Figure J-1 depicts the density, represented by total MW per 50 km^2, for operational wind energy facilities in Canada, and Figures J-2 to J-4 depict operational projects in greater detail in southern Ontario, the Atlantic Provinces, and Alberta and Saskatchewan [370].

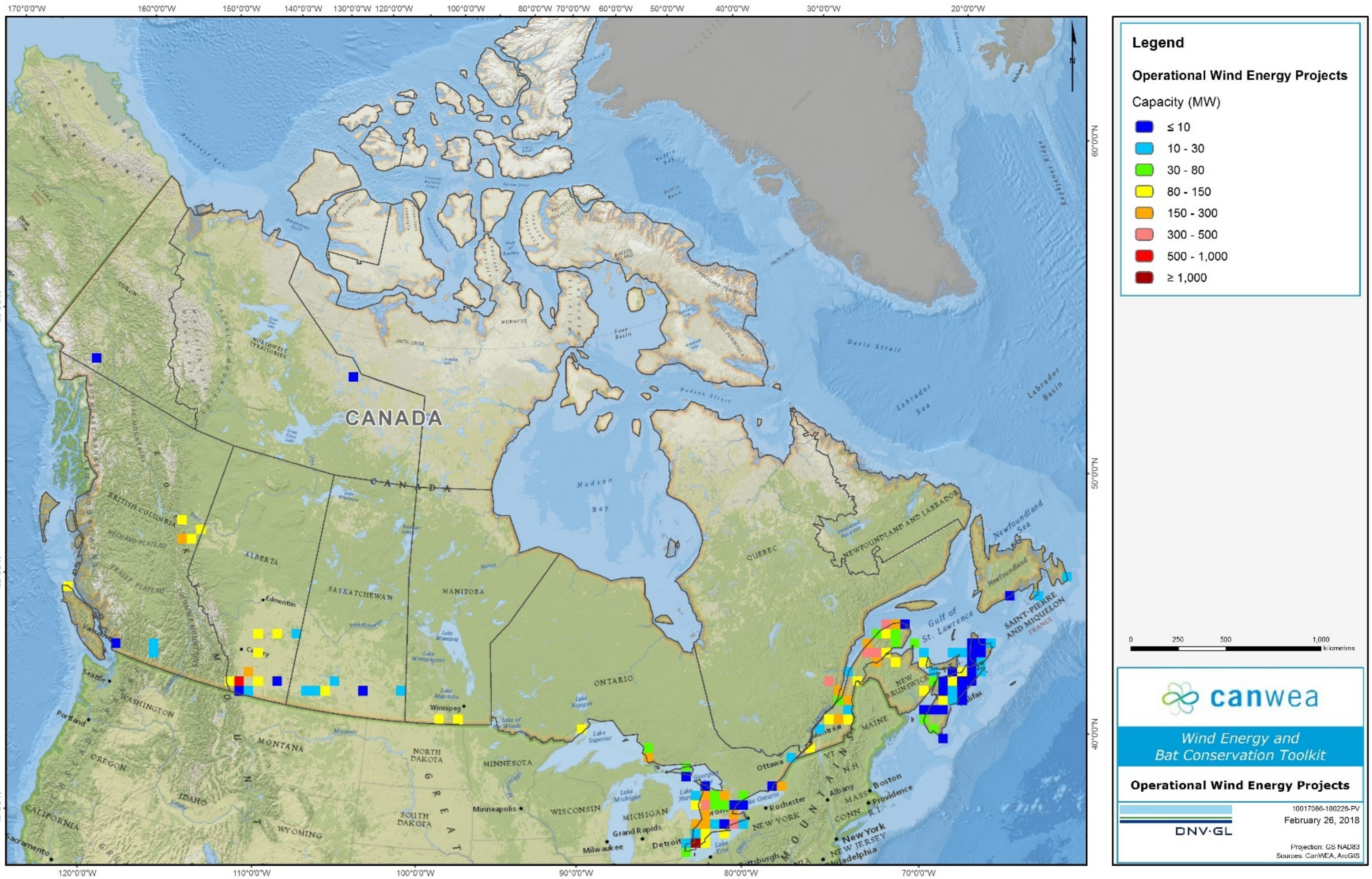


Figure J-1. Operational Wind Energy Projects in Canada, as of 31 December 2017 [370]**.**

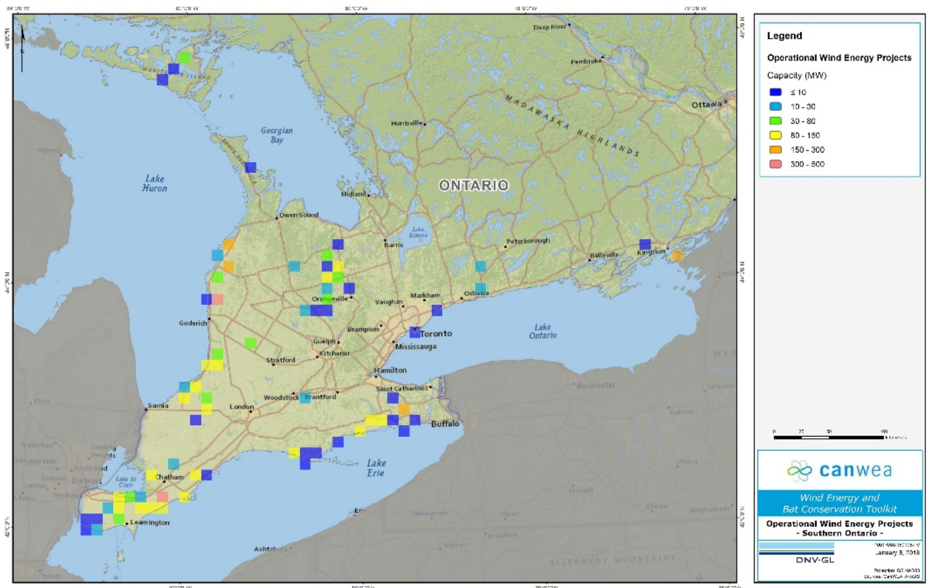


Figure J-2. Operational Wind Energy Projects – Southern Ontario, as of 31 December 2017 [370]**.**

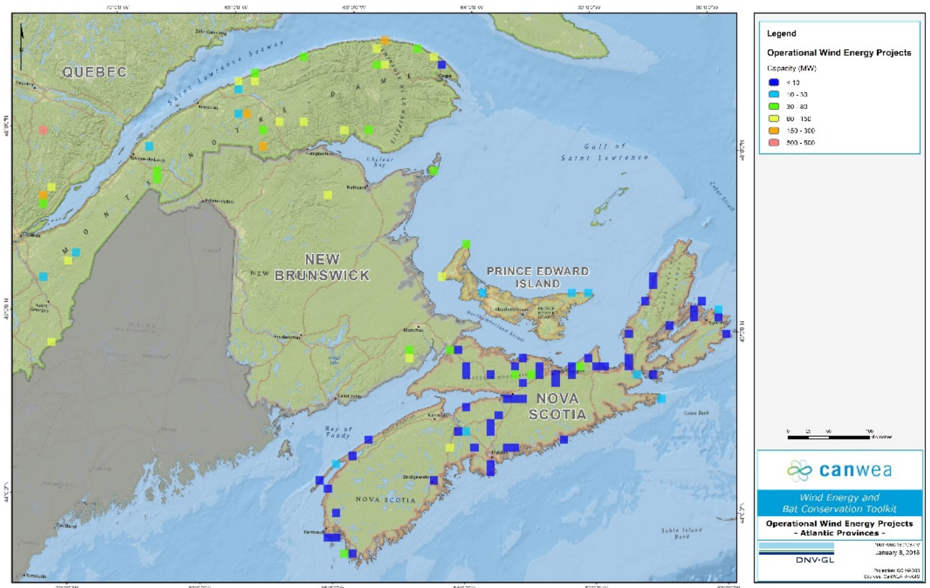


Figure J-3. Operational Wind Energy Projects – Atlantic Provinces, as of 31 December 2017 [370]**.**

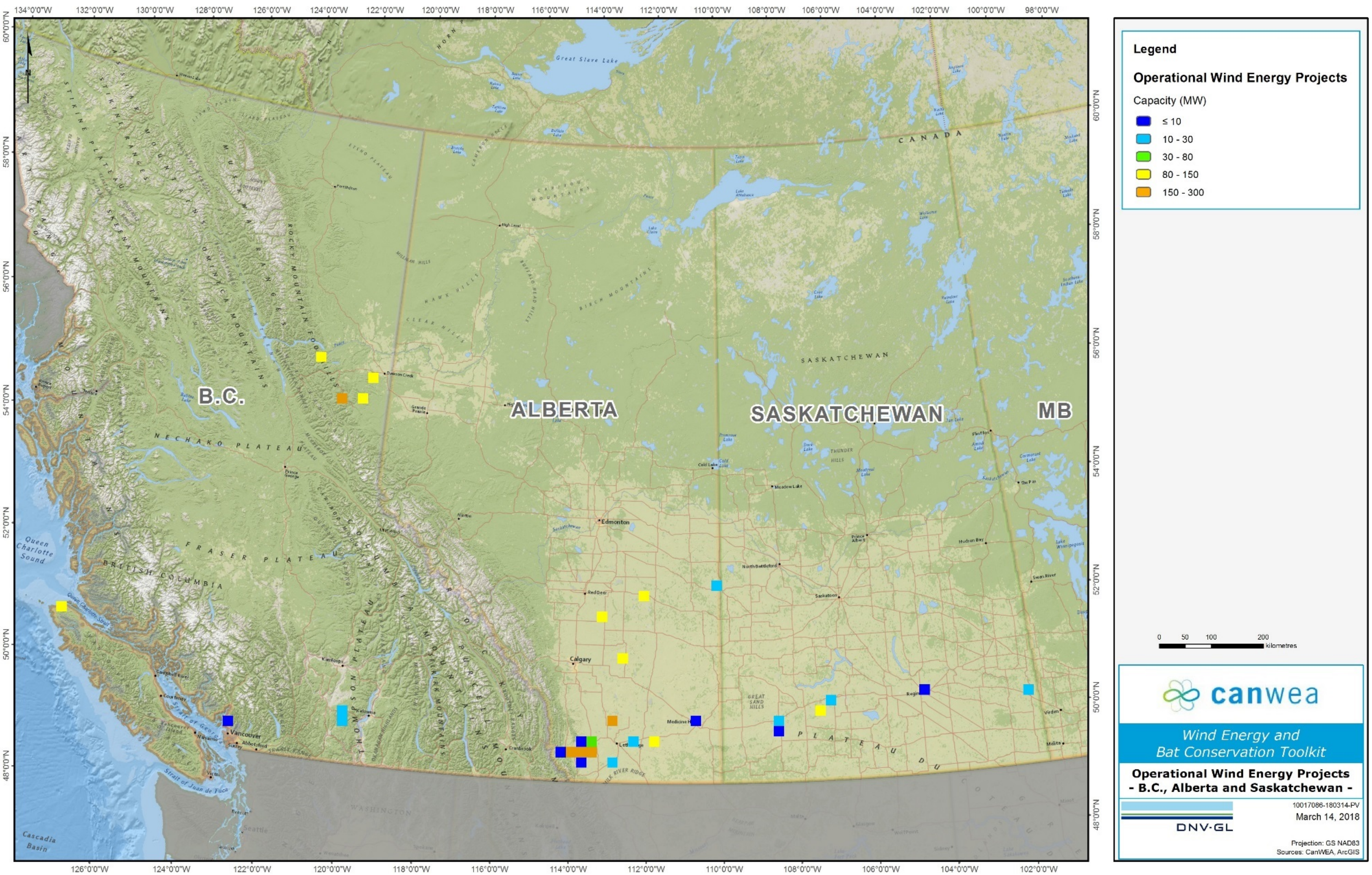


Figure J-4. Operational Wind Energy Projects – B.C., Alberta, and Saskatchewan, as of 31 December 2017 [370].

Title:	CanWEA Wind Energy and Bat Conservation Review	DNV GL - Energy
Presented to:	Canadian Wind Energy Association (CanWEA)	Advisory Americas
Contact person:	Brandy Giannetta	4100 Molson Street, Suite 100
Date of issue:	13 August 2018	Montreal, QC, H1Y 3N1, Canada
Project No.:	10017086	+1 541-272-2175
Document No.:	10017086-HOU-R-01-F	www.dnvgl.com
Issue/Status:	F/FINAL	

Task and objective: Develop a Wind Energy and Bat Conservation Review to inform decisions and facilitate communication among industry, regulatory agency, conservation organization, academic and public stakeholders.

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☐ Published

Keywords: bat, wind energy, conservation, review, Canada

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