BMP Series

Best Management Practices Guidelines for Bats in British Columbia

CHAPTER 1: INTRODUCTION TO BATS OF BRITISH COLUMBIA




February 2016

Ministry of Environment

This page has been intentionally left blank

Executive Summary

The British Columbia Ministry of Environment has developed this document to provide development proponents, researchers, consultants and British Columbia ministry staff with information about the potential impacts of resource development on the bats and their habitats in British Columbia, and guidelines on how to minimize those impacts. Chapter 1 presents a biological and ecological review of the bats of British Columbia. It includes:

- a summary of the legislation in British Columbia and Canada that protects bats and their habitats;
- a review of current provincial status designations for British Columbia's bats, and an account of their distributions within the province;
- an overview of bat biology, including descriptions of roosting and foraging habitat, area requirements, and activities by season;
- a review of existing and emerging threats to British Columbia's bats and their habitats, including habitat loss, degradation, and fragmentation; effects of pesticide use on bats; White-nose Syndrome (a recent and advancing wildlife crisis in North America); and effects of climate change on bats;
- a glossary;
- a list of references to additional information sources and provincial contacts; and,
- an appendix providing a literature review of distance travelled and flight heights of British Columbia bats.

Chapters 2–9 present Best Management Practices that are specific to each of eight development sectors that have potential effects on bats and their habitats: mining, cave and crevice use, wind energy development, forestry, hydroelectric power generation, oil and gas development, agriculture, and urban development. The Best Management Practices provide proponents guidelines to mitigate potential effects on bats associated with each type of resource development.

Some of the issues discussed in this document are subject to ongoing research; therefore, the Best Management Practices may change as results of this research become available. Readers should access the latest version of this document. All activities related to assessing the quality of bat habitat or the impact of activities on bats should involve an experienced bat biologist.

Acknowledgements

This document, the Introduction to British Columbia's Best Management Practices Guidelines for Bats, was written by Susan Holroyd (Holroyd Consulting) and Dr. Vanessa Craig (EcoLogic Research). The document is based on the Bat Conservation Strategy for British Columbia and Alberta (Craig and Holroyd 2004). Input and review was provided by Dr. Purnima Govindarajulu (B.C. Ministry of Environment), Lisa Wilkinson (Alberta Sustainable Resource Development, Wildlife Section), Dr. Robert Barclay (University of Calgary), Juliet Craig (Silverwing Consulting), Dr. Cori Lausen (Wildlife Conservation Society Canada), Laura Friis (B.C. Ministry of Environment), Dr. Jennifer Psyllakis (B.C. Ministry of Environment), Karen Wipond (B.C. Ministry of Forests, Lands and Natural Resource Operations), Kari Nelson (B.C. Ministry of Environment), and members of the British Columbia Bat Action Team (BC BAT). Thanks to everyone who provided photos free of cost. Thanks to Al Hicks, Ted Down, Dave Fraser and Brenda Hartley for facilitating the review and approval process. Funding was provided by the B.C. Ministry of Environment and the Habitat Conservation Trust Foundation.

Photos front page, left to right: Hoary Bat, Lorraine Andrusiak; Keen's Myotis, Doug Burles; Keen's Myotis, Dr. Brock Fenton; Big Brown Bat, Susan Holroyd.

Document citation:
B.C. Ministry of Environment. 2016. Best Management Practices for Bats in British Columbia, Chapter 1: Introduction to the Bats of British Columbia. B.C. Ministry of Environment, Victoria, BC. 108 pp.

Table of Contents

Best Management Practices for Bats in British Columbia: the Overall Document

Purpose/Scope

This document is written for proponents and qualified professionals involved in the resource development projects, bat biologists, and personnel of British Columbia ministries who manage bat populations and habitats in the province.

The document consists of an introductory chapter, followed by eight resource sector-specific Best Management Practices chapters that present guidelines to mitigate potential direct and indirect impacts on bats and their habitats. The overall document structure is as follows:

- Chapter 1: Introduction
- Chapter 2: Mines
- Chapter 3: Cave and Crevice Use
- Chapter 4: Wind Energy Developments
- Chapter 5: Forestry
- Chapter 6: Hydroelectric Power Generation Developments
- Chapter 7: Oil and Gas Developments
- Chapter 8: Agriculture
- Chapter 9: Urban Developments and Bridges

Resource development and human activities have the potential to disrupt wildlife and wildlife habitats. Projects developed within the Ministry of Forests Lands and Natural Resource Operations framework, have to identify potential effect on "valued components", which not only include wildlife but also economic and social values (Environmental Assessment Office 2013*a,b*). For some projects, one of the "valued components" identified may be bats and bat habitats. In addition to project specific impacts, cumulative effects of multiple projects and resource sectors need to be considered (B.C. Ministry of Environment 2014*a*). While the primary goal of most projects is to avoid impacts, in some cases this is not possible. In these cases, implementation of mitigation measures should follow the mitigation hierarchy procedures of the B.C. Ministry of Environment (B.C. Ministry of Environment 2012; B.C. Ministry of Environment 2014*a*). Updates and additional information on the mitigation policy are available on the Ministry of Environment mitigation policy website.

This series of best management practise documents provide guidelines to minimize and mitigate impacts on bats and bat habitats, and support the provincial policies described above.

How to Use the Document

The introductory chapter provides summary research on bat biology, and quantitative data to provide context and biological justification to the sector-specific recommendations and guidelines in the following chapters. Not all the resource-specific chapters have been completed at the time of web-posting.

Some of the issues discussed in this document are subject to ongoing research; therefore, the document will be updated as information becomes available. Proponents and researchers should ensure they have the latest version of this document before commencing activities. All activities related to assessing the quality of bat habitat or the impact of activities on bats should involve an experienced bat biologist.

Hyperlinks (underlined in blue) connect to information within the document or on the World Wide Web. Links to the World Wide Web (www) will open in a separate window.

Chapter 1 – Introduction to the Bats of British Columbia

1.1 Introduction

Bats are an ecologically and economically important part of ecosystems in British Columbia. Recent studies have evaluated their economic importance, especially their role as controllers of insect populations. Boyles et al. (2011) estimated that bats provide US$3.7–$53 billion per year in pest control for agricultural crops in the United States (calculated as the cost of pesticide materials and application services). However, their estimates do not account for benefits beyond the agricultural sector, such as the benefits bats provide in urban environments and in controlling forest insect pests. For example, the Long-eared Myotis (*Myotis evotis*) eats spruce budworm caterpillars, a significant forest pest (Wilson and Barclay 2006). In addition, moths are an important component of the diet of many of British Columbia's bats, and research suggests that at least some bat species provide important pest control of forest insects during insect outbreaks (Wilson and Barclay 2006). Moths (Lepidoptera) and beetles (Coleoptera) comprise 96% of the major forest pests in the Nelson Forest Region (Unger and Stewart 1992), and diet studies of bats in the region found a prevalence of these two orders of insects in bat fecal pellets (Grindal 1996). Although there was no increase in bat activity levels related to an insect outbreak, at least some species (aerial-foraging Myotis: *M. evotis*, and *M. californicus*/*M. lucifugus*/*M. yumanensis*/*M. volans*) responded by consuming large numbers of the Spruce Budworm moths during an outbreak (J. Wilson, pers. comm.). The same species also consumed caterpillars of the moths at similar rates, possibly by catching caterpillars hanging from silk threads (Wilson and Barclay 2006).

Big Brown Bats (*Eptesicus fuscus*) are one of British Columbia's larger bat species. Photo: Jared Hobbs.

The most common bats in British Columbia, the Little Brown Bat (*Myotis lucifugus*) and the Yuma Myotis (*Myotis yumanensis*) are efficient predators of flying insects. Laidlaw and Fenton (1971) calculated that a colony of 100 Little Brown Bats would eat ~19 kg (42 lbs) of insects over a 4-month period. Big Brown Bats forage primarily on beetles and true bugs, including cucumber beetles, June bugs, green and brown stinkbugs, and leafhoppers, all of which are considered to be agricultural and urban pests. It is estimated that over a single summer, a colony of 150 Big Brown Bats could consume 38,000 cucumber beetles, 16,000 June bugs, 19,000 stinkbugs, and 50,000 leafhoppers (Whitaker 1995). By eating 38,000 cucumber beetles, Big Brown Bats would control about 33 million cucumber beetle larvae, which are a significant agricultural pest in the U.S. Midwest (Whitaker 1995).

Bats may serve as bio-indicators of climate change and habitat deterioration. Their position in the food chain as predators makes them vulnerable to accumulations of toxins and pesticides. Their low reproductive rate means that bat populations may change perceptibly when even small changes in the environment such as depression of insect production affect population dynamic parameters such as growth and reproductive rates. Responses to stressors can be measured through both changes in relative and species assemblages (Jones et al. 2009; Adams 2010; Skalak et al. 2012).

1.2 Goal and Objectives

The goal of this chapter is to provide background information that will put the Best Management Practices guidelines and recommendations of later chapters into context.

This chapter's seven sections address the following objectives:

1. provide information about the relevant provincial and federal legislation that protects bats and their habitat;
2. describe the bat species found in British Columbia, and their status and distribution;
3. describe the ecology, life history, and behaviour of bats;
4. describe habitat selection and use, with particular focus on roosting and foraging;
5. briefly describe existing and emerging threats to bats;
6. provide a glossary of terms to enhance understanding of technical and bat-specific terminology; and,
7. provide additional resources and contact information for regional biologists.

Townsend's Big-eared Bat is a blue-listed species in B.C. Photo: Vanessa Craig.

Section 1: Legislation/Regulations Concerning Bats

The *Wildlife Act* protects all bat species in British Columbia from being killed, wounded, captured, hunted, trapped, or transported. There are other limited abilities under the *Wildlife Act* to protect the habitat of any wildlife species, including those designated as Endangered or Threatened. With consent from cabinet, the Minister of Forests, Lands and Natural Resource Operations may make a regulation to designate a Wildlife Management Area (WMA) under section 4 of the *Wildlife Act*. Land within a WMA may be further designated by the Minister as a Critical Wildlife Area if it is required for habitat of a species designated as Endangered or Threatened under the Act. The Critical Wildlife Area designation does not presently provide any additional legislated protective measures than those associated with general WMA designation. The Lieutenant Governor in Council, the Minister, and the *Wildlife Act* Regional Manager may make certain regulations and orders to protect species and their habitats within a designated WMA. If the Lieutenant Governor in Council considers that a species of wildlife is threatened with imminent extinction throughout all or a significant portion of its range in British Columbia because of human actions, they may, by regulation, designate that species as an endangered species. As well, if a species is considered likely to become endangered, the Lieutenant Governor in Council may designate that species a threatened species. Currently, no bat species have been designated as Endangered or Threatened under the *Wildlife Act*.

Northern Myotis (*Myotis septentrionalis*) is on the Blue List in British Columbia. Photo: Cori Lausen, Kaslo, B.C.

The *Forest and Range Practices Act* (FRPA) and its supporting regulations, as well as the *Land Use Objectives Regulation* under the *Land Act*, set the planning and practice requirements of Crown forest and rangeland, and private lands that are managed as part of a tree farm licence or woodlot licence. Under this legislative framework, bat habitat may be conserved by "coarse-filter" biodiversity provisions, such as riparian management areas, wildlife tree retention, or old growth management areas. FRPA also includes several "fine-filter" biodiversity provisions that are enabled if a species is identified as a species at risk, due to threats from forest or range activities, under the

Government Actions Regulation. Keen's Myotis (Chatwin 2004), Fringed Myotis (Sarell 2004*a*), and Spotted Bat (Sarell 2004*b*) are identified as species at risk under FRPA. The Identified Wildlife Management Strategy is the supporting policy for implementing the fine-filter provisions, specifically Wildlife Habitat Areas, Wildlife Habitat Features, and General Wildlife Measures. General wildlife measures set the practice requirements within a wildlife habitat area (e.g., prohibit timber harvesting).

Specific Wildlife Habitat Features (WHFs) for bats have been proposed by the British Columbia Ministry of Environment, but the order has not yet been made (as of 2015). The current proposal would provide additional protection to:

1. a feature used by bats to hibernate during the winter, unless it is determined that none of the following species is using the feature: Fringed Myotis, Keen's Myotis, Little Brown Myotis, Northern Myotis, Pallid Bat, Spotted Bat, Townsend's Big-eared Bat, and Western Small-footed Myotis;
2. a feature that "houses" an aggregation of bats and their young, unless it is determined that none of the following species is using the feature: Fringed Myotis, Keen's Myotis, Little Brown Myotis, Northern Myotis, Pallid Bat, Spotted Bat, Townsend's Big-eared Bat, and Western Small-footed Myotis; and
3. a maternity roost used by a Pallid Bat, Townsend's Big-eared Bat, Spotted Bat, Keen's Myotis, Northern Myotis, or Fringed Myotis.

If the WHF order is approved, authorized persons conducting primary forest activities must not damage or render ineffective a WHF unless they are granted an exemption by the Minister of Environment or delegate (under section 70, *Forest Planning and Practices Regulation*).

Some bat habitats, such as riparian areas (potential tree roosting sites) and wetlands (potential foraging sites), are incidentally protected under other legislation. Under the *Fish Protection Act*, the *Riparian Areas Regulation* requires tree retention along streams in some parts of the province (such as Vancouver Island, the Lower Mainland, and the Kootenays); these trees may provide habitat for bats. The degree of protection depends on the size of the stream and whether it is a fish-bearing stream and is in a community watershed (Forest Practices Code of British Columbia 1995). Streams in community watersheds and fish-bearing streams that are > 1.5 m wide are protected by a 20–50 m wide riparian reserve zone and an additional 20 m wide management zone. Activities are limited within the riparian reserve zone but vary greatly within the management zone. Retention rates within the management zone vary with the size of the watercourse. Streams that do not meet the > 1.5 m wide criterion for fish-bearing or community watershed streams do not have a reserve zone, and the management zone varies from 20 to 40 m wide. Wetlands have varying degrees of protection, depending on their size, location, and landscape considerations.

The federal *Species at Risk Act* (SARA) was established to prevent wildlife species in Canada from disappearing; provide for the recovery of wildlife species that are extirpated (no longer exist in the wild in Canada), endangered, or threatened as a result of human activity; and manage species of special concern to prevent them from becoming endangered or threatened. The status of Canadian wildlife and flora is assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Recommendations from COSEWIC inform the federal government's decisions to add a species to the List of Wildlife Species at Risk (Schedule 1 of SARA). Once a species is listed, prohibitions against harm apply to the listed species on federal lands, and to migratory birds and aquatic species on other lands. If the Province does not provide protection for listed species on other lands, the federal government may invoke a "safety net" order under SARA.

The migratory, solitary tree-roosting Hoary Bat (*Lasiurus cinereus*) is found throughout British Columbia. Photo: Cori Lausen, Kaslo, British Columbia.

Section 2: Bat Species - Their Status and Distribution

2.1 Status of Bats in British Columbia

Sixteen species of bats occur in British Columbia, and they are found in every region of the province (Table 1). An accidental occurrence of another species, Big Free-tailed Bat (*Nyctinomops macrotis*), was recorded in New Westminster in 1938 (Nagorsen and Brigham 1993) and acoustically recorded on the Sunshine Coast in July 2014 (C. Currie, C. Lausen and C. Corben, pers. comm.). The Canyon Bat (*Parastrellus hesperus*) may soon officially be added to the provincial list after bat specialists recorded a call from this species in southwestern British Columbia in 2013 (M. Sarell and C. Lausen, pers. comm). With only 19 species in all of Canada, British Columbia has more bat species than any other province.

More than half of the 16 bat species in British Columbia are considered to be at risk. Three of these, Keen's Myotis (*Myotis keenii*), Eastern Red Bat (*Lasiurus borealis*), and Pallid Bat (*Antrozous pallidus*), are on the provincial Red List (Endangered or Threatened). Five other species, Western Small-footed Myotis (*Myotis ciliolabrum*), Fringed Myotis (*Myotis thysanodes*), Northern Myotis (*Myotis septentrionalis*), Townsend's Big-eared Bat (*Corynorhinus townsendii*), and Spotted Bat (*Euderma maculatum*), are on the provincial Blue List, which includes species that are considered to be sensitive or vulnerable to population declines.

Table 1. Bat conservation status and distribution by region in British Columbia (B.C.).

Common Name	Scientific Name	Status	Ministry of Environment Region								
			Vancouver Island	Lower Mainland	Thompson	Kootenay	Cariboo	Skeena	Omineca	Okanagan	Peace
			1	2	3	4	5	6	7	8	9
Pallid Bat	*Antrozous pallidus*	T[b]; Red-listed (B.C.)								X	
Townsend's Big-eared Bat	*Corynorhinus townsendii*	Blue-listed (B.C.)	X	X	X	X	X			X	
Big Brown Bat	*Eptesicus fuscus*	Not at risk	X	X	X	X	X	X	X	X	X
Spotted Bat	*Euderma maculatum*	SC[b]; Blue-listed (B.C.)			X		X			X	
Silver-haired Bat	*Lasionycteris noctivagans*	Not at risk	X	X	X	X	X	X	X	X	X
Eastern Red Bat	*Lasiurus borealis*	Red-listed (B.C.)		X						?	X
Hoary Bat	*Lasiurus cinereus*	Not at risk	X	X	X	X	X		X	X	X
Californian Myotis	*Myotis californicus*	Not at risk	X	X	X	X	X	X		X	
Western Small-footed Myotis	*Myotis ciliolabrum*	Blue-listed (B.C.)			X	X	X			X	
Long-eared Myotis	*Myotis evotis*	Not at risk	X	X	X	X	X	X	X	X	X
Keen's Myotis	*Myotis keenii*	Red-listed (B.C.)	X	X			X	X		?	
Little Brown Myotis	*Myotis lucifugus*	E[a]	X	X	X	X	X	X	X	X	X
Northern Myotis	*Myotis septentrionalis*	E[a]; Blue-listed (B.C.)				X	X	X	X		X
Fringed Myotis	*Myotis thysanodes*	Blue-listed (B.C.)	?	?	X	X	X			X	
Long-legged Myotis	*Myotis volans*	Not at risk	X	X	X	X	X	X	X	X	X
Yuma Myotis	*Myotis yumanensis*	Not at risk	X	X	X	X	X	X		X	

[a] Assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) during an emergency assessment in February 2012, and recommended for listing on Schedule 1 under the *Species at Risk Act*

[b] T = Threatened; SC = Special Concern; listed on Schedule 1 by COSEWIC

Table adapted and updated from Nagorsen and Brigham (1993).

At the federal level, four bat species in British Columbia are listed or assessed as species at risk or potentially at risk under SARA. COSEWIC lists the Pallid Bat as Threatened and the Spotted Bat as a species of Special Concern. A federal Emergency Assessment Subcommittee of COSEWIC recently assessed the Little Brown Myotis and the Northern Myotis as Endangered, and recommended that they be listed on Schedule 1 of SARA, as of February 2012, primarily due to extensive mortality caused by White-nose Syndrome (WNS) at hibernation sites in the eastern parts of their ranges in Canada. They were officially listed as endangered in December 2014. Two other bat species in British Columbia—Fringed Myotis and Keen's Myotis—have been listed as "data deficient" by COSEWIC since 2004.

More information about British Columbia's species at risk listing is available at the BC Species and Ecosystems Explorer. Data on the animals and ecosystems at risk in British Columbia are managed by the British Columbia Conservation Data Centre (CDC). Along with species status, the CDC tracks the locations and level of protection of these species and ecosystems. The British Columbia Ministry of Environment has also established a Wildlife Species Inventory, which allows users to search for all wildlife species occurrences, including at-risk species and non-sensitive species, in an area by name or by ecosystem type, and to learn about threats and means for protection. Inventory data, inventory methodologies, reports, and maps are available using the Species Inventory Database and the Species Inventory Web Explorer.

The Best Management Practices described in this document apply to all bat species in British Columbia. Extra care is required for species that are listed as of conservation concern federally or provincially; where data are lacking, the precautionary principle is invoked when considering management options.

Big Brown Bats are found throughout British Columbia. Photo: Paul Faure, McMaster University.

2.2 Distribution of Bats by Region and Biogeoclimatic Zones

Bat species diversity in British Columbia varies by region: the warmer southern region of the province supports more species than the northern region. The Thompson-Okanagan region and the warm, dry areas of the Cariboo support the greatest diversity of bats. The ranges of some bat species extend across the entire province; others are more restricted (Table 1). It should be noted, however, that a lack of detections in some regions may simply be an artifact of limited inventory and inadequate sampling. For example, the Eastern Red Bat (*Lasiurus borealis*) was recently confirmed as breeding in the boreal forests of northern Alberta. Its presence in the boreal forests of British Columbia was detected only recently as a result of increased bat monitoring conducted for wind energy development environmental impact assessments (Nagorsen and Paterson 2012). The Hoary Bat is also likely a breeding resident in British Columbia's boreal forest region. Recent work has confirmed that the Fringed Myotis occurs in the west Kootenay valley (Hill et al. 2007). Records of this species from coastal Oregon (Adam and Hayes 2000) suggest that it likely resides in coastal British Columbia as well; however, inventory for this species in coastal British Columbia has been limited.

Habitat capability/suitability modelling has been completed for several bat species in the south Okanagan (Warman et al. 1998; Sarell and Haney 2000), and for the Western Small-footed Myotis in the Milk River area of Alberta (Jones et al. 2003). These models can predict where cave and crevice roosting bats may be found based on current geological and terrestrial ecosystem mapping, and represent a first step in identifying potentially

Canada's largest bat species is the Hoary Bat (*Lasiurus cinereus*); concerns for this species arise from elevated mortality rates at wind energy developments. Photo: Dr. Cori Lausen.

Table 2. Bat species associations with biogeoclimatic zones in British Columbia (adapted and updated from Nagorsen and Brigham 1993).

Common Name	Scientific Name	Biogeoclimatic Zone[a]													
		CDF	CWH	MH	BG	PP	IDF	MS	ICH	SBPS	SBS	ESSF	SWB	BWBS	AT
Pallid Bat	*Antrozous pallidus*				●	●									
Townsend's Big-eared Bat	*Corynorhinus townsendii*	●	●		●	●	●		●						
Big Brown Bat	*Eptesicus fuscus*	●	●		●	●	●	●	●	●	●			●	
Spotted Bat	*Euderma maculatum*				●	●									
Silver-haired Bat	*Lasionycteris noctivagans*	●	●	●	●	●	●	●	●		●	●	●	●	
Eastern Red Bat	*Lasiurus borealis*		●		●										
Hoary Bat	*Lasiurus cinereus*	●	●		●	●	●	●	●			●			
Californian Myotis	*Myotis californicus*	●	●		●	●	●	●	●			●			
Western Small-footed Myotis	*Myotis ciliolabrum*				●	●	●								
Long-eared Myotis	*Myotis evotis*	●	●	●	●	●	●	●	●	●	●	●			
Keen's Myotis	*Myotis keenii*	●	●											●	
Little Brown Bat	*Myotis lucifugus*	●	●	●	●	●	●	●	●	●	●	●	●	●	
Northern Myotis	*Myotis septentrionalis*								●	●	●			●	
Fringed Myotis	*Myotis thysanodes*				●	●	●								
Long-legged Myotis	*Myotis volans*	●	●	●	●	●	●	●	●	●	●	●		●	
Yuma Myotis	*Myotis yumanensis*	●	●		●	●	●	●	●						

[a] CDF= Coastal Douglas-fir, CWH = Coastal Western Hemlock, MH = Mountain Hemlock, BG = Bunchgrass, PP = Ponderosa Pine, IDF = Interior Douglas-fir, MS = Montane Spruce, ICH = Interior Cedar-Hemlock, SBPS = Sub-Boreal-Pine-Spruce, SBS = Sub-Boreal Spruce, ESSF = Engelmann Spruce-Subalpine Fir, SWB = Spruce-Willow-Birch , BWBS = Boreal White and Black Spruce, AT = Alpine Tundra (BC MOF 2014).

suitable habitat. Table 2 lists bat species by biogeoclimatic zone in British Columbia, based on modelling and surveys conducted in the province. In some cases, these predictions alone could be used for preliminary land use planning. However, site-specific field investigations are required to determine the validity of the predictions and to identify key bat roosting sites so that these and buffer habitat can be properly protected.

Section 3: Bat Biology and Seasonal Activity Cycles

This section provides an overview of bat activity and life stage in each season. Type of activity and life stage influences habitat selection (discussed in Section 4) and sensitivity to disturbance and threats (discussed in Section 5). The annual cycle of bat activity can be divided into winter hibernation, spring migration and initiation of pregnancy, summer foraging, reproduction (birth of young, nursing, weaning and flight of young) and fall migration and mating. Although the exact timing of these phases varies by region and annual climatic conditions, the approximate annual cycle is represented in Figure 1.

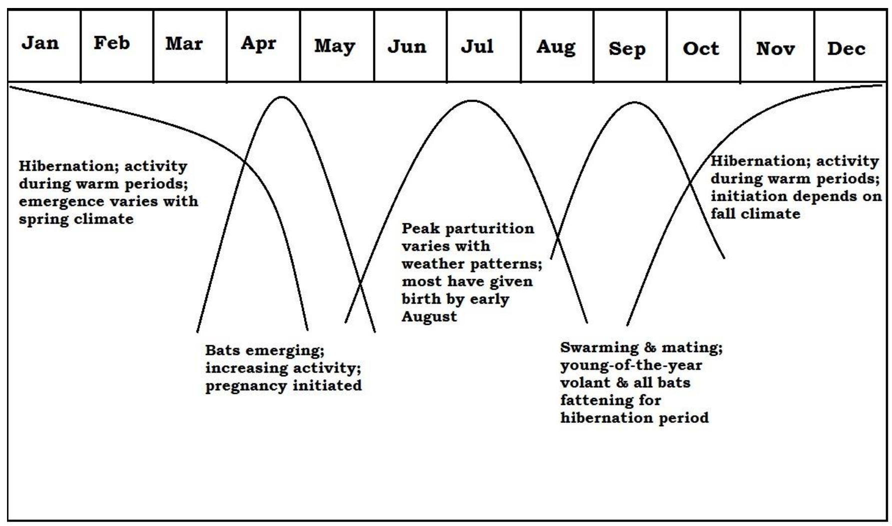


Figure 1. General pattern of annual activity of bats in British Columbia; the pattern varies with climatic region in the province (figure by S. Holroyd).

3.1 Winter

Most bats in British Columbia hibernate during the winter. During this period, they are in a torpid, inert state with their body temperature just above ambient temperature and their heart and metabolic rates drastically reduced to minimize energy use. It was assumed that bats wake periodically during winter to drink, and then they return quickly to hibernation until spring temperatures are warm enough to support insect prey. However, bats have recently been observed waking during winter and feeding on insects within their hibernation site and other locations where there may be food available (C. Lausen, pers. comm.). In addition, acoustic monitoring throughout the winter in the Kootenays and Okanagan, and on Vancouver Island has recorded bat echolocation calls, in particular those of Californian Myotis (C.

Lausen, unpublished data). In order to better understand the needs of bats during winter, ongoing research in British Columbia is focusing on determining the reasons for winter activity and its frequency of occurrence, distances moved by bats, and which species are most likely to remain active during winter.

Hibernating Townsend's Big-eared Bat, Vancouver Island. Note that its long ears are curled up in a "ram's curl" position while hibernating. Photo: EcoLogic Research, Gabriola Island, B.C.

Bats in British Columbia are thought to hibernate between November and April; however, recent monitoring of bat activity in winter indicates that there is tremendous variation among regions, between years, and among species (C. Lausen, unpublished data, Grindal et al. 1992). Given this new emerging information, bat hibernation periods need to be assessed at a site-specific level until region and species specific recommendations can be developed.

Bats are vulnerable to predation and disturbance while hibernating. Torpid bats cannot rouse quickly to respond to threats. Bats roused from this state use up valuable fat reserves, which puts them at risk of starving to death before insect prey are available in the spring (Thomas et al. 1990; Thomas 1995). This threat is particularly acute for smaller individuals, which do not have significant fat reserves. It is estimated that only 40–50% of young bats survive their first winter (Humphrey 1975). Arousal during winter can negatively influence population growth rates because females emerging from hibernation with severely depleted fat reserves may not be able to support successful implantation and gestation of pups (Holroyd 1993).

Little Brown Myotis hibernating in Cadomin Cave, Alberta. Banded bat in photo was 39 years old in 2013. Photo: Chuck Priestley. Information: Dave Hobson.

Much of the information on bat survival rates and longevity is from capture-mark-recapture studies conducted at hibernation sites because bats return to these sites year after year. Annual adult survival rates can be high (e.g., 0.79 for Big Brown Bats), and longevity can reach 19 years (e.g., Big Brown Bats) (Hitchcock 1965) or more for Little Brown bats (e.g., 20–30 years, with a maximum of 41 years), which is highly unusual for such small-bodied mammals (Wilkinson and South 2002; Podlutsky et al. 2005). However, these estimates may represent unusual circumstances. For example, life expectancy for Big Brown Bats in some studies ranges between 5.65 and 6.65 years (O'Shea et al. 2011).

3.2 Spring

Generally, bats start to become active in April in most regions of British Columbia when warm ambient temperatures prompt the emergence of insect prey. Bats may become active earlier than April (as early as February) in areas of the province with milder climate, such as areas in the south coast. Emergence can also vary from year to year depending on annual variation in weather patterns. Little is known about the movement of bats in spring as they transition between winter and summer habitats. Our understanding of bat behaviour in winter and early spring is rapidly evolving as there are more projects studying bat winter ecology in B.C. in preparation for the management of White-nose Syndrome should it arrive as predicted in the next 10-15 years.

Baby Yuma Myotis, Cortes Island, B.C. Photo: Christian Gronau.

Resident female bats may become pregnant in the spring immediately following their first winter as young-of-the-year because males will mate with all available females in fall prior to hibernation at a hibernation site, even if females are already hibernating (Kunz and Fenton 2006). In B.C., there is evidence of mid-winter mating in some species like the Silver-haired Bat and Townsend's Big-eared Bat (C. Lausen, pers. comm). Females store sperm over winter, and fertilization occurs when they ovulate in spring. Maintaining a pregnancy depends on the female's body condition; not enough fat reserves and poor spring conditions may cause the pregnancy to fail. Under ideal conditions, most females produce one large offspring, which may weigh up to 25–30% of the mother's body mass at birth (Barclay and Harder 2003). A few species, including the Big Brown Bat, have more than one pup. The twinning rate for Big Brown Bats is much higher in eastern Canada than in the west (Holroyd 1993). The Lasiurines (Hoary and Red Bats) and Silver-haired Bats commonly produce twins in other parts of their range in North America, and Red Bats have been known to produce litters of four (Nagorsen and Brigham 1993). No specific research on reproduction in Big Brown, Hoary, Red or Silver-haired Bats has been conducted in British Columbia.

Spotted Bat (*Euderma maculatum*) found in the South Okanagan, B.C. Photo: Dr. Michael Proctor.

Reproductive females are greatly affected by climatic conditions, especially in early spring and summer. Cold, wet spring conditions cause declines in flying insect activity and production, which reduces the amount of food available to hungry bats. To compensate for cool environmental conditions and low food availability in spring, females reduce their energy demands by using daily torpor to lower their body temperature and metabolic rate (Racey and Swift 1981). Females use torpor more commonly during pregnancy than lactation (Holroyd 1993). Use of torpor slows fetal growth rates and can delay the birth of pups by 2–3 weeks (see Figure 1 for general timing of reproduction). This allows females to maintain their pregnancies in a stalled state of development until they can adequately meet the energy demands of the growing fetus (i.e., when warmer environmental temperatures result in both greater prey availability and less energetic demand to maintain their own body temperature) (Barclay and Harder 2003). However, the disadvantage of a late birth date is that it reduces the time available for pups to achieve adult size, master flight and hunting techniques, and store fat reserves for winter hibernation.

Little is known about reproductive strategies of migratory Lasiurine bat species (Hoary and Red Bats), which are thought to be active year-round. Females arrive at their spring breeding range pregnant. It is thought they mate sometime during the southern fall migration, store sperm over winter, and initiate pregnancy in the spring. These bats may exhibit flocking behaviour (i.e., large groups of bats flying together as a group) during the fall migration, and this is assumed to favour breeding aggregations. The Lasiurines have a larger litter size than non-migratory species; producing two pups may be a way of compensating for mortality during migration. The Lasiurines are solitary, and females roost alone with their pups (Nagorsen and Brigham 1993).

3.3 Summer

In summer, bats focus on foraging to increase energy reserves. Building up energy reserves is important for reproductive females; it allows them to successfully nurse and support growing pups. Larger fat reserves increase the chances of overwinter survival and reproduction the following year.

In British Columbia, the numbers of births likely peak from late June until mid-July (but there will be annual variation around these dates depending on variation in spring weather conditions and/or region within the province). Following birth, lactation continues until the pup learns to fly and feed itself (Figure 1). Peak energy demands on the mother occur when she is nursing an almost fully grown infant that is expending large amounts of energy learning to fly, which usually happens when pups are 3–5 weeks old (approximately late July and early August). At this time, nursing females may consume their own weight in insects each night to meet their energy demands (Kurta et al. 1989).

Bats in British Columbia are insectivores: they primarily eat flying insects, but some bats include spiders in their diets (Table 3). Small bats eat small insects, such as mosquitoes, midges, lacewings, small moths, caddisflies, and other small night-flying invertebrates (Table 3). Larger bats can consume larger insects, such as large moths and larger hard-bodied beetles (Table 3). These insects develop in a number of different aquatic environments ranging from lakes, small pools, and ditches to swift-moving streams. Lower elevation riparian habitat can be particularly insect-productive, and is especially important for reproductive females because it provides both food and water (Grindal et al. 1999). Bats are opportunistic and will fly and forage wherever patches of flying insects arise.

Table 3. Diets and foraging mode of bats of British Columbia.

Species	**Diet** (Aquatic insects[1] shown in italics, taxonomic groups are listed in order of frequency in diet composition studies)	**Foraging Mode**	**Reference** (D = diet; M = foraging mode)
Little Brown Myotis	*Midges, mosquitoes*, *mayflies (Ephemeroptera), flies (Diptera),* beetles (Coleoptera)[2], *caddisflies (Trichoptera),* lacewings (Neuroptera), Hymenoptera, and moths (Lepidoptera).	Aerial; nimble flyer, above water; above shrub layer	Belwood and Fenton 1976 (D); Anthony and Kunz 1977 (D); Fenton et al. 1980 (M); Herd and Fenton 1983 (DM); Saunders and Barclay 1992 (DM); Whitaker and Lawhead 1992 (D); Rainey 1998 (D); Burles et al (2008); Clare et al. 2011(D)
Yuma Myotis	Moths (Lepidoptera), *midges, mosquitoes, caddisflies (Trichoptera), flies (Diptera)*, and small beetles (Coleoptera).	Aerial; similar to Little Brown Myotis	Fenton et al. 1980 (M); Herd and Fenton 1983 (DM); Brigham et al. 1992 (D); Bogan et al. 1998a (D)
Californian Myotis	*Caddisflies (Trichoptera)*, moths (Lepidoptera), *flies (Diptera).*	Aerial; adept at flying in clutter	Fenton et al. 1980 (M); Simpson 1993 (D); Chung-MacCoubrey 1996 (D)
Western Small-footed Myotis	*Caddisflies (Trichoptera), flies (Diptera),* beetles (Coleoptera) and moths (Lepidoptera), true bugs (Hemiptera).	Aerial; adept at flying in clutter	Fenton et al. 1980 (M); Woodsworth et al. 1981 (D); van Zyll de Jong 1985 (D)
Long-legged Myotis	Primarily moths (Lepidoptera), *flies (Diptera)*, beetles (Coleoptera).	Aerial, high above ground and at cliff tops	Warner and Czaplewski 1984 (DM); Saunders and Barclay 1992 (DM); Johnson et al. 2007 (D); Ober and Hayes 2008 (D)
Long-eared Myotis	Moths (Lepidoptera), *flies (Diptera)*, beetles (Coleoptera), as well as lacewings (Neuroptera), wasps, and true bugs (Hemiptera).	Gleaner, but capable of aerial foraging	Black 1974 (D); Whitaker et al. 1977 (D); Manning and Jones 1989 (D); Faure and Barclay 1994 (DM); Bogan et al. 1998b (DM); Lausen and Hill 2010 (M)
Northern Myotis	*Caddisflies (Trichoptera)*, moths (Lepidoptera), beetles (Coleoptera), *flies (Diptera)*, and leafhoppers (Hemiptera).	Gleaner, but capable of aerial foraging	Nagorsen and Brigham 1993 (DM); Caceres and Pybus 1997 (M); Caceres 1998a,b (M)
Keen's Myotis	Moths (Lepidoptera; dominant part of the diet in the Queen Charlotte Islands [QCI]), spiders (Arachnidae, Araneae [also dominant in QCI]), *flies (Diptera),* lacewings (Neuroptera), true bugs (Hemiptera), Hymenoptera, and barklice (Psocoptera [at low levels in QCI]), and *caddisflies (Tricoptera)*	Gleaner, but capable of aerial foraging	Parker and Cook 1996 (D); Burles et al 2008 (D); Burles 2001 (D)

Species	Diet (Aquatic insects[1] shown in italics, taxonomic groups are listed in order of frequency in diet composition studies)	Foraging Mode	Reference (D = diet; M = foraging mode)
Fringed Myotis	Beetles (Coleoptera), small moths (Lepidoptera), *flies (Tipulidae; Diptera)*, spiders (Araneida), leafhoppers (Hemiptera), lacewings (Neuroptera), crickets (Gryllidae), harvestmen (Phalangida)	Gleaner; 3–10 m above ground at treetops near vegetation	Black 1974 (D); Whitaker et al. 1977 (D); O'Farrell and Studier 1980 (DM); Warner 1985 (D); Collard et al. 1990 (M); Nagorsen and Brigham 1993 (D); COSEWIC 2004 (DM)
Silver-haired Bat	Mainly moths (Lepidoptera), *chironomids, Diptera, caddisflies (Trichoptera),* other insects	Aerial; above treetops, over open meadows, above riparian	Whitaker et al. 1981 (D); Kunz 1982a (D); Barclay 1986 (M); Ober and Hayes 2008 (D)
Eastern Red Bat	Moths (Lepidoptera), beetles (Coleoptera)	Aerial; high, fast flier	Shump and Shump 1982a (DM)
Hoary Bat	Primarily moths (Lepidoptera), but also flies (Diptera), grasshoppers (Orthoptera), termites, *dragonflies (Odonata)*, wasps (Hymenoptera), and beetles (Coleoptera)	Aerial; high flying above treetops	Shump and Shump 1982b (DM); Barclay 1985,1986 (M); Bolster 1998 (D); Barclay et al. 1999 (M); Ober and Hayes 2008 (D); Valdez and Cryan 2009 (D)
Big Brown Bat	Primarily beetles (including important agricultural pests), but also true bugs (Hemipterans), flies (Dipterans), moths (Lepidopterans), *caddisflies (Trichopterans)*, and Hymenopterans	Aerial; generalist, but above foliage	Kurta and Baker 1990 (D); Brigham 1991 (M); Whitaker 1995 (D); Perkins 1998 (D)
Spotted Bat	Mainly moths (Lepidoptera), few beetles (Coleoptera), few grasshoppers (Orthoptera)	Aerial; high flying above treetops; flies in circuits;	Ross 1967 (D); Easterla and Whitaker 1972 (D); Watkins 1977 (DM); Fullard et al. 1983 (D); Leonard and Fenton 1983 (M); Wai-Ping and Fenton 1989 (M);
Townsend's Big-eared Bat	Primarily moths (Lepidoptera), but also lacewings (Neuroptera), dung beetles (Coleoptera), *flies (Diptera)*, and sawflies (Hymenoptera)	Gleaner	Kunz and Martin 1982 (D); Nagorsen and Brigham 1993 (DM); Ober and Hayes 2008 (D)
Pallid Bat	Mainly beetles (Coleoptera), moths (including sphingids, Lepidoptera), grasshoppers/crickets (Orthopterans), mantids, few lacewings (Neuroptera)	Gleaner	Grindal et al. 1991 (DM); Chapman et al. 1994 (DM)

[1]Aquatic species have aerial adult phases but lay eggs and have larval forms that live in an aquatic environment. As a result, "hatches" of insects usually arise over aquatic habitats.

[2]Coleopteran group (beetles) may include both aquatic and non-aquatic species.

Some insect species found in bat diets are commonly associated with upland habitats (i.e., developmental stages are dependent on terrestrial vegetation rather than an aquatic environment). They include moths (Lepidoptera), lacewings (Neuroptera), some beetles (Coleoptera), spiders (Arachnidae), wasps (Hymenoptera), barklice (Psocoptera), crickets (Gryllidae), harvestmen (Phalangida), leafhoppers (Homoptera), grasshoppers (Orthoptera), termites (Isoptera), and sawflies (Hymenoptera) (Table 3).

Open ponds and riparian wetlands are important for bats. Photo: Jennifer Gleason.

Several families of moths, including Geometrids, Notodontids, Arctiids, Lymantrids, Noctuids, and Sphingids, are likely important prey for bats (especially for moth specialists, such as Townsend's Big-eared Bat) (Table 3). Plant understorey and tree cover influence the composition and abundance of the insect community in an area. Moths generally feed on plant material ranging from decaying fruit and plant matter to grasses, shrubs, and trees (Milne and Milne 1988). Native shrubs (such as willow [*Salix* spp.], cherry [*Prunus* spp.], and various deciduous tree species) and a number of common wildflower species (fireweed [*Epilobium* spp.], evening-primrose [*Oenothera* spp.], thimbleberry [*Rubus parviflorus*], and others) support a number of Sphingid moth species (Borkent and Greenway 1997) that may occur in bat diets. High-elevation "moth-aggregation areas" have been identified as an important part of late-season habitat of grizzly bears (French et al. 1994). These areas could also be important for bats that are in the process of fattening-up for hibernation. There is evidence that high-elevation habitats are important for bats, especially in the late season in British Columbia (Kellner 1999).

Most bats consume insects in mid-flight (known as "aerial hawking"), although a few species can hover in flight and are capable of "gleaning" or picking moths and other insects off surfaces, such as leaves or tree bark. In the south Okanagan, the Pallid Bat may glean large insects off the desert floor; in more southerly parts of its range, it is known to take scorpions (Nagorsen and Brigham 1993). Gleaning bat species are more likely to listen for prey, and subsequently have large ears (e.g., Townsend's Big-eared Bat, Pallid Bat). Townsend's Big-eared Bats are capable of slow hovering flights, and their quiet echolocation calls allow them to glean moths off leaf surfaces. The Long-eared Myotis (*Myotis evotis*, *M. keenii,* and *M. septentrionalis*) uses similar strategies for capturing insects (Faure et al. 1993).

During summer, bats often fly significant distances between day-roosting habitat and nightly foraging habitat using tree-lines, riparian habitats and watercourses, and forest edge habitat as landscape guidance features for their commute (Grindal et al. 1999). Commuting distances vary by species (Fenton 1997), and commuting behaviour patterns within a given community of bats depend on the species present and the sex, age, and reproductive condition of individuals.

Larger bat species (such as the Big Brown Bat, Silver-haired Bat, or Lasiurines) are known to fly farther than smaller species (such as the *Myotis* species or Townsend's Big-eared Bat) on a given foraging night. High, fast-flying species, such as Big Brown Bats and Hoary Bats, travel long distances (6–20 kilometres in one direction), often through open airspace, and make fast, direct flights to forage or drink on a nightly basis (Barclay 1984, 1985; Fenton 1997; Wilkinson and Barclay 1997). Bat species classified as gleaners (Table 3), such as the slow-flying Townsend's Big-eared Bat, typically forage close to roosts. Studies of a similar species (of the genus *Corynorhinus*) in the U.S. indicated that foraging distances for breeding females varied with the age of their young. Females with non-volant pups foraged up to three times per night and ranged less than 1 kilometre from the roost, but females with older pups ranged from 2 to 4 kilometres (Clark et al. 1993). Smaller bat species (such as the small Myotis species) may avoid openings (Limpens et al. 1989, cited in Erickson and West 1996), and bat species such as *Myotis septentrionalis* (and possibly *M. evotis and M. keenii*) may be classified as "forest-interior" specialists (Doucett et al. 2002; Broders et al. 2006). See Appendix A for a more complete review of distances travelled and flight heights of British Columbian bat species.

Recent work has also shown that individual bats rely on memory of their surroundings to form maps, which they use in future flights (Barchi et al. 2012). Spatial modelling of bat foraging habitat of two Mediterranean bat species indicated that distance to water explained more than 75% of the use of space by foraging bats (Rainho and Palmeirin 2011). This and other research suggests that the importance of drinking water resources for bats should not be underestimated (Adams 2010).

3.4 Fall

Migration can be defined as a seasonal, two-way movement, from one place or habitat in one season to another the following season to avoid unfavourable climatic conditions or gain abundant seasonally available resources (Fleming and Eby 2003). Although migration is a two-way movement, much of what is known about migration focuses on fall migratory behaviour for bats. Bat species vary in the distances they migrate, and can be grouped according to three categories: long-distance, regional, and sedentary (Fleming and Eby 2003). Long-distance migrators have highly developed migratory behaviour: individuals sometimes travel more than 1000 kilometres between summer and winter habitats (Fleming and Eby 2003). Long-distance migrators in British Columbia include the Red, Hoary, and Silver-haired Bat. Silver-haired Bats have also been called "migratory hibernators" in British Columbia because they move from northern locations to more southern locations within the province before hibernating (Schowalter et al. 1978; Nagorsen and Brigham 1993); recent evidence of year-round site fidelity of male Silver-haired bats in the Kootenay region indicates that migratory behaviour may be sex-biased in this species (Lausen and Hill 2016). In late August to early September, Hoary Bats move south, possibly as far as Mexico or Central America, and spend the winter hunting there before returning to breed in British Columbia. Little is known about the populations, movement patterns, or migratory routes of these three high-flying and fast-flying bat species.

Regional migrants move moderate distances of 100–500 kilometres between summer and winter roosts, and include species such as the Little Brown Myotis (Fleming and Eby 2003). Little Brown Bats in Ontario are known to move up to 200 kilometres between summer breeding areas and their hibernation site at a mine (Fenton 1969).

Sedentary species breed and hibernate in the same local areas, and usually move less than 50 kilometres between summer and winter roosts. Sedentary species may include the Big Brown Bat, Townsend's Big-eared Bat, and Pallid Bat (Fleming and Eby 2003) and California Myotis (C. Lausen, pers. comm). The maximum recorded distance Townsend's Big-eared Bat moved between summer and winter habitats is 40 kilometres (Humphrey and Kunz 1976).

Mating may also occur during fall, at special swarming sites, although swarming may also occur at a hibernation site. Swarming serves a social function for bats: it allows individuals to find mates from different summer colonies (Bat Conservation Trust 2007), and it may be a way for adult bats to "show" juveniles where important hibernation sites are located (Fenton 1969). Swarming activity is characterized by intense chasing flights in and around underground sites by large, transient, often multi-species assemblages (Glover and Altringham 2008). Activity occurs between August and October before bats enter hibernation for the winter.

Surveys using automated echolocation call detection systems are an easy and unobtrusive way to identify important cave swarming sites for bats (Glover and Altringham 2008). Swarming sites represent hotspots for gene flow between otherwise isolated bat populations (Glover and Altringham 2008). A single swarming site may serve a population from a radius of at least 60 kilometres around the site (Bat Conservation Trust 2007).

Section 4: Habitat Use by British Columbia Bats

Bats require two major types of habitat: roosting habitat, which varies by season, species, sex, life stage, and time of day (Table 4), and foraging/drinking habitat, which varies with species and season. Bats have other minor but essential habitat requirements, such as specialized swarming habitats, and safe migrating and commuting habitats, which may not be used often or for long durations but are still essential to maintain stable populations.

4.1 Roosting Habitat

Roosts vary by season (summer, fall, and winter) and by time of day (day-roosts and night-roosts). Suitable roosting habitats, especially maternity roosts and hibernation sites, are critical resources for bats in summer and winter.

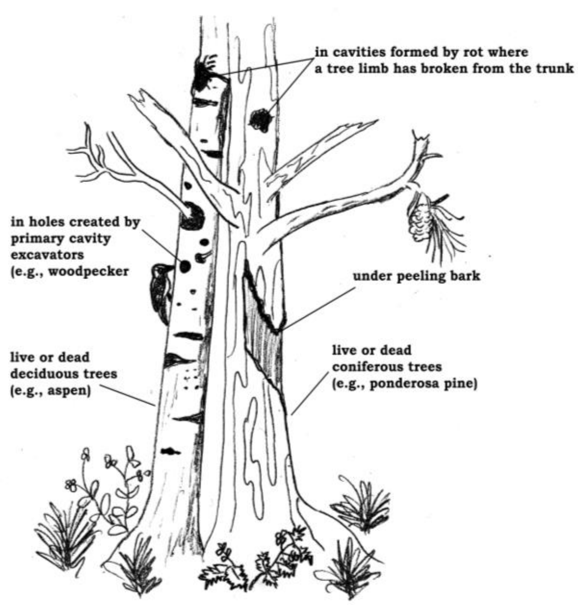


Figure 2. Bat roosts can be in live or dead, deciduous or coniferous trees. Tall, large diameter trees with roosting features (crevices, peeling bark, or cavities) are favoured (figure by S. Holroyd).

During the active summer period, bats spend their day at day-roosts. Bats in British Columbia day-roost in diverse habitats, including dead and live trees (Figure 2), geological formations (caves, rock crevices, cliffs), mines, buildings, under bridges (Perlmeter 1996), and in artificial bat houses (Table 5) (Kiser and Kiser 1999; Kellner and Rasheed 2001, 2002; Craig 2003; Nagorsen 2009). During summer, different species select different day-roosting habitat; sex and reproductive condition also influence roost choices. Males and non-reproductive females tend to use cooler day-roosts than breeding females, use torpor more often, and roost either in small numbers or by themselves (Grinevitch et al. 1995). Some species, such as the Silver-haired Bat, Hoary Bat, and Red Bat, roost exclusively in trees in the summer; other species are more diverse in their choice of roosts (Table 5).

Night-roosts are used during the active summer period. Bats congregate at these sites after their first big foraging bout of the evening. At a night-roost, bats group together to stay warm, digest their meal, and pass fecal pellets before resuming the nightly hunt for

Table 4. Bat roost types and their definitions.

Roost Type	Definition
Ephemeral roost	A bat roost in a feature where the characteristics important to bats (e.g., microclimate) may change quickly and/or unpredictably; for example, an area under sloughing tree bark.
Permanent roost	A roost that is available for bat use over many years and has suitable characteristics (e.g., microclimate, access) that remain stable over time. Examples of permanent roosts include caves, cliffs, mines, bridges, buildings, and large hollow trees of a slow-decaying species, such as western redcedar (*Thuja plicata*).
Night-roost	A roost where bats rest at night between foraging bouts. Bats may roost singly or congregate.
Day-roost	A roost where bats rest during the day in spring/summer/autumn. Day-roost types include maternity roosts, bachelor roosts, and mixed male/non-reproductive female/yearling groups. Use of a specific day-roost may be seasonal or variable within a season.
Maternity roost	A roost used outside the winter period by adult females that are capable of reproduction.
Nursery roost	A roost where females congregate to give birth and raise their young (adapted from Knight and Jones 2009). A nursery roost is a type of maternity roost.
Bachelor roost	A roost used by one or more males during the day.
Fall migratory rest stop	A roost used by bats during migration between summer and winter habitats.
Winter hibernation roost	A site where one or more bats hibernate in winter (hibernacula [plural]). A given hibernaculum may be used by bats for only part of the winter, and may not be used every winter.

insects. Bridges, buildings, mine entrances, and hollow trees are examples of habitats used as night-roosts.

Roost sites can be classified as permanent or ephemeral based on the longevity of site conditions and fidelity of bats to a particular site. Geological formations and structures such as buildings or bridges may be considered relatively permanent because they remain in place for many decades and provide predictable, stable environments in terms of temperature and humidity. These roosts may be considered to be of higher quality and value than roosts that are more ephemeral (Lewis 1995). Ephemeral roosts are available and/or suitable for bats for only a relatively short time. Ephemeral roosts include most types of tree roosts, such as roosts under sloughing bark (although hollow western redcedar can remain in place for many years and are considered by most biologists to be ecological gems on the landscape). Ephemeral bat roosts under sloughing bark are typically found in dead coniferous trees and/or live trees with injuries that provide roost spaces in cracks or holes, or under bark (Brigham et al. 1997b; Rabe et al. 1998; Barclay and Brigham 2001). Snags with sloughing bark remain available on the landscape for a relatively short time (compared to live healthy or declining trees) before they break off or fall over. In addition, the favoured roost characteristics associated with sloughing bark (primarily thermal characteristics) appear to change relatively rapidly as bark is lost, which results in frequent roost switching and low roost fidelity (Lewis 1995; Rabe et al. 1998; Barclay and Brigham 2001). Roosts within erosion crevices in large river banks (Lausen and Barclay 2006) may be an important roost type for a number of bat species, but may be affected by climate and erosion processes, which makes them more of an ephemeral-type roost.

Bats may switch roosts in response to a change in roost microclimate or condition, to reduce parasite load, to relocate closer to favourable foraging areas, in response to disturbance or predation risk, or so that young will become familiar with alternative roost sites (Lewis 1995; Rabe et al. 1998). Bat species that use permanent roosts exhibit less roost-switching behaviour than species that use ephemeral roosts, such as trees (Lewis 1995). Increased fidelity to permanent roost types makes some bat species more vulnerable to local extirpation if there is a limited number of roosts available or known to them, and especially if the roosts are removed from the landscape or made ineffective as a result of human disturbance or modification (e.g., destruction of cliff faces or caves, modification of cave environments, disturbance at roost sites, or capping of mines).

Permanent roosts should receive a higher level of protection and management than ephemeral roosts. Areas of the landscape with ephemeral roost habitat should be actively managed to maintain and recruit suitable amounts of roost habitat over time. Management decisions should focus on protecting permanent roosts from degradation, disturbance, or loss.

Table 5. Known roosting preferences of British Columbia bats in summer and winter (some information is from research conducted outside the province).

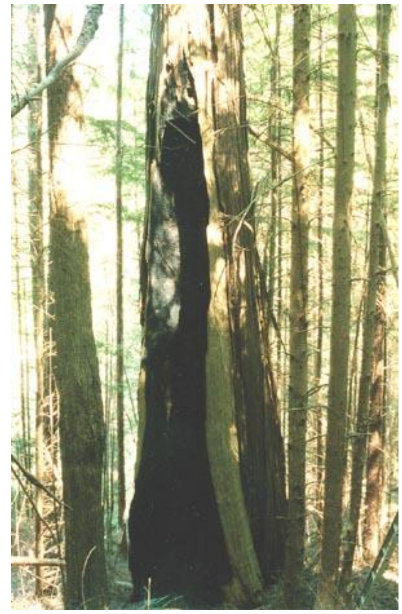
Species	Summer Roosts[a,b]							Winter Roosts[a]
	Trees	Rock crevices, outcrops	Cliffs	Mines	Buildings	Bridges	Bat houses	
Little Brown Myotis	D	Y	Y	Y	Y	Y	Y	Mines, caves
Yuma Myotis	D	Y	N	Y	Y	Y	Y	Mines, buildings
Long-legged Myotis	D, Stump	Y	Y	N	S	N	N	Mines, caves
Western Small-footed Myotis	N	Y	Y	Y	S	N	N	Mines, cliff crevices
Californian Myotis	D	Y	N	Y	S	Y	Y	Buildings, mines, caves
Fringed Myotis	D	Y	N	Y	S	N	N	Mines
Long-eared Myotis	D, Stump	Y	Y	N	S	N	Y	Mines, buildings
Keen's Myotis	D	Y	N	Y		N		Dead/dying trees, rock crevices
Northern Myotis	D	N	N	N	R	N		Mines
Townsend's Big-eared Bat	Y (big)[c]	N	Y	Y	Y	P	Y (big)[c]	Mines, caves
Eastern Red Bat	L	N	N	N	N	N	N	Migrates
Hoary Bat	D, L	N	N	N	N	P	N	Migrates
Silver-haired Bat	T, L	N	N	N	N	N	N	Dead/dying/live trees, mines, buildings; migrates
Big Brown Bat	D	Y	Y	N	Y	Y	Y	Buildings, mines, rock crevices
Pallid Bat	D	N	Y	Y	P	N	N	Rock crevices
Spotted Bat	N	N	Y	N	N	N	N	Cliffs, mines

[a] Sources: Nagorsen and Brigham 1993; Sarell and Luoma 1994; Rasheed and Holroyd 1995; Vonhof and Barclay 1996, 1997; Rabe et al. 1998; Barclay and Brigham 2001; Holloway and Barclay 2001; Fenton et al. 2002; Rambaldini 2003; Lausen and Hill 2016

[b] D = dead/dying; L = live; T = in furrows on the surface of tree bark; Y = Yes, N = No, S = Sometimes, R = Rarely, P = Potential (known to do so elsewhere, not known for British Columbia)

[c] "big" tree roosts include very large hollow trees (e.g., Western redcedar); "big" bat houses are akin to small sheds or buildings built specifically for this species.

4.1.1 Summer Roosts in Trees



Bat roost in a hollow western redcedar with a breeding colony of Yuma Myotis, Cortes Island, B.C. Photo: Christian Gronau, Cortes Island, B.C.

Most bats in British Columbia roost at some time in trees under loose bark, in tree cavities or openings, or in foliage (Nagorsen and Brigham 1993; Crampton and Barclay 1998; Barclay and Brigham 2001; Parsons et al. 2003; Willis et al. 2003; Brigham 2007) (Table 6). Many species, even those that are not typically considered to be tree-roosting bats, such as the Townsend's Big-eared Bat, also use tree roosts for night-roosting (e.g., Roberts and Roberts 1996) (Table 5). Important tree types include tall trees, dead or dying trees, older age class trees with peeling bark, trees with crevices from lightning strikes or other damage, or trees with cavities (e.g., created by primary cavity excavating birds, such as woodpeckers) (Brigham 2007) (Figure 2). Cavities are available in live and dead, coniferous and deciduous trees; however, natural large cavities tend to be rare on the landscape (Bonar 2000).

Bats inside a Yuma Myotis roost tree (hollow western redcedar), Cortes Island, B.C. Photo: Christian Gronau, Cortes Island, B.C.

Although the type of tree day-roost selected (i.e., under bark, in foliage, or in a cavity, and tree species) may vary among bat species, the characteristics of the roost trees selected are generally similar (Brigham et al.1997*a*). Roost trees are typically large in diameter and height (Crampton and Barclay 1998; Ormsbee and McComb 1998; Waldien et al. 2000; Weller and Zabel 2001), dead trees are slightly to moderately decayed (Maser et al 1979; Sasse and Pekins 1996; Lacki and Schwierjohann 2001; Weller and Zabel 2001), and roosts are in older forested stands (Perkins and Cross 1988; Betts 1996; Vonhof and Barclay 1996a, 1996b, 1997; Crampton and Barclay 1998; Brigham 2007).

Table 6. Examples of tree species used for roosting by bats in British Columbia (B.C.). References include studies conducted outside of British Columbia but within the species' North American distribution range.

Species	Location	Roost	Reference
Little Brown Myotis or Yuma Myotis	Coastal B.C.	Large western redcedar (*Thuja plicata*)	van den Driessche et al. 2000
Little Brown Myotis	Central B.C.	Western hemlock (*Tsuga heterophylla*) – crack western redcedar – snags and stump	Rasheed and Holroyd 1995
Little Brown Myotis	Central Alberta	Trembling aspen (*Populus tremuloides*) snags	Crampton and Barclay 1996
Little Brown Myotis	Saskatchewan	Trembling aspen (declining live trees and snags)	Kalcounis and Hecker 1996
Yuma Myotis	Kootenays, B.C.	Tree stump	Vonhof and Barclay 1997
Californian Myotis	Southern Interior B.C.	Most notably Douglas-fir (*Pseudotsuga menziesii*) snags, but also grand fir (*Abies grandis*) and western white pine (*Pinus monticola*) snags	Brigham et al. 1997b
Long-legged Myotis	Central B.C.	Douglas-fir – crack from lightning strike	Rasheed and Holroyd 1995
Long-legged Myotis	Oregon	Primarily Douglas-fir snags, but also western hemlock and western redcedar snags (fire-hollowed), and some live Douglas-fir trees	Ormsbee 1996
Long-legged Myotis	Oregon	Large Douglas-fir snags	Ormsbee and McComb 1998
Long-eared Myotis	Kootenays B.C.	Tree stumps – ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*) preferred, but also used western redcedar, Douglas-fir, grand fir, western hemlock, and Western white pine	Vonhof and Barclay 1997
Long-eared Myotis	Oregon	Primarily Douglas-fir snags, but also used western hemlock and Douglas-fir stumps	Waldien et al. 2000
Northern Myotis	Northeastern B.C.	Trembling aspen and balsam poplar (*Populus balsamifera*)	Vonhof and Wilkinson 1999, 2000
Fringed Myotis	Northern California	Douglas-fir snags	Weller and Zabel 2001
Big Brown Bat	Kootenays B.C.	Ponderosa pine	Brigham et al. 1997b
Big Brown Bat	Southern B.C.	Douglas-fir snags	Rasheed and Holroyd 1995
Big Brown Bat	Southern B.C.	Trembling aspen snags	Vonhof 1996a
Big Brown Bat	Southern B.C.	Trembling aspen cavities	Rasheed and Holroyd 1995
Big Brown Bat	B.C.	Ponderosa pine snags	Brigham 1991
Big Brown Bat	Saskatchewan	Trembling aspen cavities	Kalcounis and Brigham 1998
Big Brown Bat	Saskatchewan	Trembling aspen cavities	Willis et al. 2003
Big Brown Bat	Oregon	Ponderosa pine	Betts 1996
Silver-haired Bat	Coastal B.C.	Large western redcedar	van den Driessche et al. 2000
Silver-haired Bat	Kootenays B.C.	Ponderosa pine	Brigham et al.

			1997b
Silver-haired Bat	Southern B.C.	Live trembling aspen (cavities)	Rasheed and Holroyd 1995
Silver-haired Bat	Southern B.C.	Trembling aspen snags preferred, but also uses Douglas-fir	Vonhof 1996a
Silver-haired Bat	Central Alberta	Trembling aspen snags	Crampton and Barclay 1996
Silver-haired Bat	Manitoba	Peach-leaved willow (*Salix amygdaloides*) and green ash (*Fraxinus pennsylvanica*)	Barclay et al. 1988
Silver-haired Bat	Oregon	Grand fir, ponderosa pine, western larch (*Larix occidentalis*)	Betts 1996
Hoary Bat	Saskatchewan	White spruce (*Picea glauca*)	Willis and Brigham 2005
Hoary Bat	Manitoba	Peach-leaved willow (*Salix amygdaloides*) and green ash (*Fraxinus pennsylvanica*)	Koehler 1991
Hoary Bat	Ontario	Mature white and red pine (*Pinus strobes, P. resinosa*) located close to flyway edges (roads, river channels); also used trees heavy with grapevine (*Vitus* spp.) overgrowth	B. Hickey, pers. comm.

Higher local densities of large snags (≥ 30 cm diameter at breast height may also determine habitat suitability (Waldien et al. 2000; Lacki and Schwierjohann 2001; Weller and Zabel 2001); however, some studies have reported that snag density may not be an important determinant of activity levels (Ormsbee and McComb 1998; Jung et al. 1999). Structural characteristics such as canopy closure, subcanopy characteristics, and understorey vegetation may also influence habitat selection (Jung et al. 1999).

Bats have also been reported roosting in stumps in clearcuts (Kalcounis and Hecker 1996; Vonhof and Barclay 1997; Waldien et al. 2000) but bats that use them may experience increased levels of predation (Vonhof and Barclay 1997). However, in managed landscapes stumps may represent important roosting habitat, and may need to be treated as a limited resource for bats.

The type of day-roost selected may vary with species, sex, size or reproductive status. For example, Silver-haired Bat roost sites vary in canopy height with bat reproductive status, age, and sex (Christy and West 1993). Male Northern Myotis roost in cavities in live trees that are smaller in diameter than those used by females, and lactating females appear to have different roost tree selection criteria than pregnant females (Lacki and Schwierjohann 2001). Although there were some difference in preference for roost trees between sexes, in general both male and female Keen's Myotis chose larger trees with defects and less bark cover, in forested areas with more old growth characteristics (Boland et al 2009). In general, smaller bat species tend to use roosts beneath bark, where available, but larger species tend to use cavities (Vonhof and Gwilliam 2000). Cavities might allow larger maternity colonies (i.e., ten or more bats) to form, depending on cavity size (Crampton and Barclay 1996; Kalcounis and Brigham 1998).

Larger colonies of bats would have thermoregulatory benefits because more bats can share warmth (Kunz 1982*b*).

Many studies indicate that some bat species prefer to roost in trees of specific species (e.g., Brigham et al. 1997b; van den Driessche et al. 2000; Vonhof and Gwilliam 2000; Vonhof and Wilkinson 2000); however, the preferred tree species may vary between areas. In some cases, the preferred species is rare on the landscape. For example, Californian Myotis in the Kootenay region of British Columbia preferred to roost in ponderosa pine (*Pinus ponderosa*) snags, and used Douglas-fir (*Pseudotsuga menziesii*) snags less than expected based on their abundance on the landscape (Brigham et al. 1997b; Barclay and Brigham 2001). This could indicate a preference for the roost characteristics of the trees, or some other landscape feature with which the tree is associated (e.g., south-facing slopes, dry habitat) (Brigham et al.

Californian Myotis roost under exfoliating bark. Photo: Dr. Robert Barclay.

1997*b*). Due to the variability in tree roost use, it is difficult to define bat habitat preferences that apply across habitat types in British Columbia; however, habitat preference (in terms of tree species, decay stage (Maser et al 1979), size, height, and site position) has implications for forest management (i.e., tree species retention, revegetation planning).

The location of roosts in the landscape is also important. Lacki and Schwierjohann (2001) reported that in Kentucky selected roost trees were not distributed equally across the landscape. Roosts were located on upper and mid-slope sites rather than on lower sites. Similar patterns have been reported for other snag-dependent bat species (Brigham et al. 1997b; Ormsbee and McComb 1998; Rabe et al. 1998). Roosting areas (snags) are also especially important near streams (Brigham et al. 1997b; Ormsbee and McComb 1998; Rabe et al. 1998). For example, Long-legged Myotis chose day-roosts near streams, especially when night-roosts were in close proximity in central Oregon (Ormsbee and McComb 1998); however, not all bats prefer to roost close to water (Ormsbee and McComb 1998; Waldien et al. 2000).

All bats choose relatively accessible roosts, but the amount of vegetation clutter that is acceptable around roosts varies. Smaller bat species, which are more manoeuvrable, will roost in more cluttered habitat than that used by larger species, such as the Hoary Bat. Because juveniles and pregnant females have reduced manoeuvrability, females may choose maternity roosts in less complex habitat because they are easier to access (Kalcounis and Brigham 1998). Roosts on the edge of roads or clearings might also have good access (Waldien et al. 2000). Some silvicultural practices, such as thinning, spacing, or brushing, might improve the accessibility of roosts in forest stands. Removing overgrowing vegetation or brushing on clearcuts may increase or maintain the suitability of stumps as bat roosts over a longer period (Vonhof and Barclay 1997). However, vegetation removal may also reduce habitat suitability by causing a decline in insect populations in the area (i.e., reduce prey availability), affecting bat survival rates (Vonhof and Barclay 1997), or increasing predation risk (Kalcounis and Brigham 1998). Jung et al. (1999) reported reduced activity of *Myotis* spp. in open-canopied stands, and suggested that it was due to increased predation risk.

Two bat species in British Columbia—Hoary Bat and Red Bat— roost in foliage in coniferous and deciduous trees (Shump and Shump 1982ab; Nagorsen and Brigham 1993; Heinrich et al. 1999; Hutchinson and Lacki 2000). Both species prefer solitary roosts in live trees, where they hang from exposed small twigs. Hoary and Red Bats are heavily furred (including their tail membrane, which they will wrap around themselves like a blanket), and their fur colour allows them to hide among the foliage. They roost in large, tall trees in forests with an open understory. It is likely that the presence of trees with suitable attributes will decline in managed forests over time (Bunnell et al. 1999) as younger forests have fewer large tall trees and the understory is more cluttered.

Willis and Brigham (2005) found that Hoary Bats chose more open roost sites on the south- and southeast-facing sides of white spruce (*Picea glauca*) in southern Saskatchewan. These roosts offered protection from the prevailing winds and reduced the energy loss associated with convective cooling in unprotected roosts. Roosts with fewer branches and less surrounding forest provided bats with clear flight paths and easier access to their roost site (Willis and Brigham 2005).

4.1.2 Summer Roosts in Geological Features and Mines

Bats in Canada use caves and mines primarily as winter hibernation sites; however, these roost types can also provide important day-roosting summer habitat for non-reproductive females and males of some species. Caves and mines are generally too cold to use as nursery roosts, but in areas with quite hot summer conditions, such as the dry Central Interior, the southern Rocky Mountain Trench, eastern Vancouver Island, and the Lower Mainland, cave-preferring species, such as Townsend's Big-eared Bat, use caves as summer nursery colonies (Schaeffer et al. 2002; Craig 2003; Hill et al. 2005, 2006a, 2006b). Cliff faces and rock formations with crevices that receive full afternoon sun and hold the heat may be important roosting habitat for reproductive females.

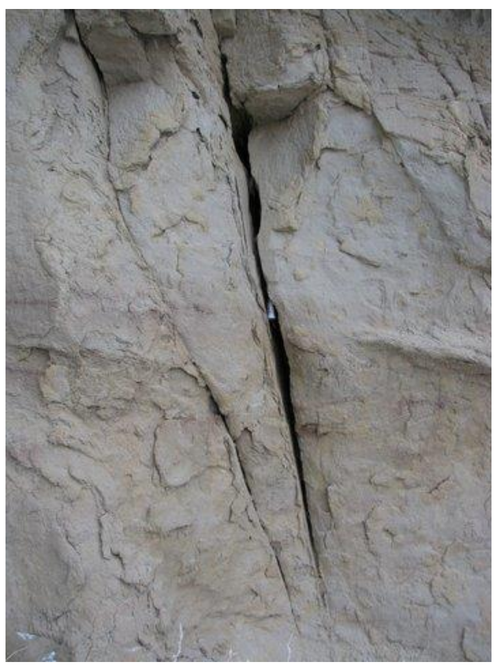
Bats exiting cave entrance. Photo: Juliet Craig, Nelson, B.C.

Keen's Myotis on Haida Gwaii have exploited a geothermally heated cave/crevice shelter as a maternity roost. However, this situation is quite unique (Burles 2000). Recent earthquake activity in 2012 resulted in the loss of the heated spring water in pools adjacent to the roost; this resulted in a marked decline in the population using the site, although predation by a local saw-whet owl (*Aegolius acadicus*) could have also contributed to this decline (D. Burles, pers. comm.).

Cave habitat may also be used in summer for night-roosting. Little is known about the night-roosting habits of bats, but research in the west Kootenays established that a few species (Long-eared Myotis, Californian Myotis, and Long-legged Myotis) use caves as night-roosts (Hill et al. 2005).

Almost all bat species in British Columbia show some preference for rock or crevice summer roosts (Nagorsen and Brigham 1993), except species that are considered to be tree dependent (i.e., Red Bat, Hoary Bat, Silver-haired Bat) (Tables 5 and 6). Townsend's Big-eared Bat, Pallid Bat, Spotted Bat, and Western Small-footed Myotis, almost exclusively prefer cave and crevice roosts. Spotted Bats are known to roost only in steep cliffs in British Columbia's dry interior (Nagorsen and Brigham 1993; Holroyd et al. 1994: Sarell and Haney 2000). Pallid Bats in the Okanagan use crevices in rocky outcrops (Chapman et al. 1994; Sarell and Haney 2000; Rambaldini 2003, 2006). Western Small-footed Myotis seems to prefer rock-type roosts (Garcia et al. 1995; Holloway and Barclay 2001). Rock crevices in cliffs and boulder fields may also provide important summer roosting habitat for Little Brown Myotis (Rasheed and Holroyd 1995).

Western Small-footed Myotis cave roost. Photo: Cori Lausen, Kaslo, B.C.



Bat winter hibernation roost in a mudstone crevice (approximately 2 metres long and 3 metres deep) in a steep riverbank in Alberta. HOBO temperature data logger is visible half way down the crack (white object). Photo: Brandon Klug, Calgary, Alberta.

Low rock outcrops and other geological formations, such as hoodoos and crevices created by erosion of streambank sediments along steep-sided rivers (such as the Fraser and Columbia Rivers in British Columbia and the South Saskatchewan and Red Deer Rivers in Alberta), also provide important summer roosting habitat for many bat species (Holloway 1998; Chruszcz 1999; Holloway and Barclay 2000; Lausen 2001, 2003; Chruszcz and Barclay 2002; Lausen and Barclay 2002, 2003, 2006; Rambaldini 2006). Species known to use erosion-type crevices include the Western Small-footed Myotis, Long-legged Myotis, Long-eared Myotis, and Big Brown Bat

Townsend's Big-eared Bat roost in a building on Quadra Island, B.C. Photo: Vanessa Craig.

(Holloway 1998; Chruszcz 1999; Holloway and Barclay 2000; Lausen 2001, 2003; Chruszcz and Barclay 2002; Lausen and Barclay 2002, 2003, 2006).

4.1.3 Summer Roosts in Buildings, Bridges, and Bat Houses

Buildings are a significant summer roost type for some bat species in British Columbia.

Little Brown Myotis and Yuma Myotis often roost in tight spaces and are the species most likely to use attics or squeeze under shakes or shingles on houses. Large colonies of 2000–4000 Yuma Myotis have been found in buildings in the North Okanagan (Milligan and Brigham 1993; Nagorsen and Brigham 1993; Holroyd et al. 1994) and in coastal British Columbia (Kiser and Kiser 1999; Kellner and Rasheed 2001, 2002). Little Brown Myotis have been found roosting with Yuma Myotis in large mixed-species colonies, but in British Columbia, colonies consisting solely of Little Brown Myotis have ranged in size from a few individuals to about 200 bats (Firman et al. 1995; Smyth 1999).

Big Brown Bats have also been found in buildings in British Columbia, and in attic roosts in buildings throughout Alberta. One of the largest known colonies in Canada, approximately 800 bats, was found in a red brick school building in Medicine Hat, but was destroyed (Schowalter and Gunson 1979). A large colony of Big Brown Bats in British Columbia would be 30–40 bats (Nagorsen and Brigham 1993). A colony of about 30 Big Brown Bats was found in a barn in the dry interior of British Columbia (Holroyd et al. 1994).

Cluster of Townsend's Big-eared Bats in a building. Photo: Juliet Craig, Nelson, B.C.

The rare Townsend's Big-eared Bat in British Columbia has shown an affinity for roosting in buildings (Firman 1997, 1999, 2003; Smyth 2000; Craig 2003; Hill et al. 2006). It uses buildings with easy access because it does not squeeze into spaces, but seems to prefer to fly through openings. These bats tend to roost in clusters from rafters in very open spaces, but this makes them vulnerable to human disturbance or injury, either by intentional or accidental means. Maternity colonies of Townsend's Big-eared Bats have been successfully protected in buildings in British Columbia (Firman 1999; pers. observ. V. Craig, S. Holroyd). In one case, this included protecting nearby hibernation sites in several local mine shafts (Firman 1999). This was an example of an ideal scenario where close proximity of summer and winter habitats provides conditions that support both greater bat abundance and diversity of bats (Findley 1993).

Western Small-footed Myotis uses roosts in buildings and bridges throughout its range (Garcia et al. 1995; Holloway and Barclay 2001). Other bat species known to use buildings as roosts in other parts of the their range include the Long-eared Myotis, Californian Myotis, and Pallid Bat (Bat Conservation International 2014) However, there are no records of these species using buildings in British Columbia.

Night-roost in a barn near the Fraser River in the Cariboo Region of British Columbia that is used by at least three bat species (Yuma Myotis, Fringed Myotis, and Townsend's Big-eared Bat). Photo: Anna Roberts.

Bat colonies in buildings provide ideal bat populations to study (Holroyd 1993; Hamilton and Barclay 1994; Grinevitch et al. 1995; Wilkinson and Barclay 1997) and have allowed for analyses of long-term data sets (Barclay 2012). A sudden decline in a stable colony may signal that there is a problem. Building surveys for bats have been conducted in the South Thompson and Shuswap areas (Firman et al. 1995) and for Townsend's Big-eared Bats on Vancouver Island and the North Gulf Islands (Holroyd and Craig 2001).

Community bat programs in the Kootenays have been tracking colonies of various bat species in buildings (J. Craig, pers. comm.). However, there have been no long-term monitoring programs until now. In 2014, a province-wide community bat program called "Got Bats?" (BC BATS 2014a) coordinated by the Ministry of Environment and a number of non-governmental stewardship groups initiated an annual bat count program to track relative abundance of bats at summer day roost sites (BC BATS 2014b). The data collected by this program may serve as an indicator of changes in bat population numbers caused by the arrival of White-nose Syndrome (USFWS 2013) and other threats.

Bridges may also provide important roosting habitat for bats, mainly as night-roosts, but they may also provide roost habitat for maternity colonies if conditions are suitable (Perlmeter 1996). Bridges make suitable bat roosts if they offer protected roost crevices and spaces, are situated where they get warmed by the sun, are constructed from materials that retain heat, and are close to water. There are several sites in the United States where bridges provide a maternity roost site for several thousand bats. Few surveys in British Columbia have focused on the use of bridges by bats, but it is unlikely that colonies as large as those in the U.S. will be found because they would have already been noticed. Newer bridge designs may not offer the roosting potential of older designs because they lack crevices and spaces where bats can find protected roosting spaces (Keeley and Tuttle 1999).

Large colonies of Yuma and Little Brown Myotis in British Columbia have been fairly successfully evicted from buildings and relocated to artificial roost structures (bat houses of varying size and design) near the original roosts (Kiser and Kiser 1999; Kellner and Rasheed 2001, 2002; Nagorsen 2009). In Campbell River, Yuma Myotis moved from one type of bat house to another, depending on the microclimates afforded by the bat house design (Nagorsen 2009). Providing a variety of styles of bat houses creates alternative available roosting habitat under seasonally variable climatic conditions.

4.1.4 Fall Roosts and Swarming Habitat

In late summer and early fall, caves (and mines) become important sites for swarming behaviour, which involves the congregation of males and females for pre-hibernation courtship and mating (Davis et al. 1999). Swarming sites play an important part in the life cycle of bats, but they have been poorly studied in British Columbia; few sites are known, and the characteristics that are important to bats are not understood. The use of automated echolocation detection systems to survey cave and mine sites is an effective and unobtrusive way to identify (Glover and Altringham 2008), and then protect these sites in British Columbia.

4.1.5 Winter Roosts

Fourteen of the 16 bat species that occur in British Columbia hibernate in mines and caves (especially in crevices, cracks, holes or other small openings inside the cave or mine), in crevices or cracks on cliffs, rock faces and rock outcrops, and other geological formations such as erosion crevices or (Table 5; Nagorsen and Brigham 1993; Nagorsen et al. 1993; Lewis 1995).

Bats appear to select hibernation sites with specific characteristics. Winter roosts in crevices have to provide stable cold temperatures and microclimate characteristics that are necessary for hibernation. Ideally, the temperature in a hibernaculum should remain fairly stable (above freezing but generally below 5–6°C) and have high relative humidity, which prevents dehydration. However, preferred microclimatic conditions in hibernation sites may vary by bat species (Nagorsen and Brigham 1993; Nagorsen et al. 1993).

Bat hibernation site in the Okanagan: mine portal with a bat gate professionally installed. Photo: Chris Godwin-Sheppard, AMEC, Calgary, Alta.

Few bat hibernacula are known in western Canada, with only four cave sites known for many years in Alberta and few in British Columbia (Bryant 1987; Nagorsen et al. 1993; L. Wilkinson, pers. comm.). Current efforts (e.g. BatCaver, www.BatCaver.org) are locating additional cave and mine sites where bats hibernate. For example, a cave hibernaculum of approximately 3000 Little Brown Myotis were recently discovered in Northwest Territories (Wilson et al. 2014), and in recent years small cave and mine hibernacula have been found in Alberta (G. Horne, pers. comm.), and in British Columbia (Lausen 2013). The largest bat hibernaculum in British Columbia as of 2016 consists of an estimated 1000-3000 bats in West Kootenay (Lausen and Isaac 2015). Because most hibernacula in British Columbia are unknown, there is a risk of losing populations or individuals due to development activities, human disturbance, and/or inadvertent spread of White-nose Syndrome.

The province is believed to have the largest concentration of caves in Canada; more than 1500 caves have been documented by cavers and resource managers, primarily within the forestry sector (P. Griffiths, pers. comm.). Crevices that may be usable by roosting bats are ubiquitous in the developed karst landscapes of British Columbia; the upper surface layers of karst (epikarst) almost always have fissures and similar types of surface openings, many of which are enlarged by solution processes. About 10% (or 100,000 km^2) of the province is underlain by soluble bedrock that has karst potential, but the extent of development of bat suitable fissures, crevices and cracks is highly variable depending the type and purity of soluble bedrock (i.e., limestone, dolomite, marble, and gypsum), physiographic location, and biogeoclimatic setting (BC MOF 2003).

Townsend's Big-eared Bat hibernaculum, Cariboo, BC. Photo: Anna Roberts.

4.2 Foraging Habitats

Preferred foraging habitat varies with bat species. Use of foraging resources is related to bat wing morphology which influences flight abilities, and echolocation call which influences the ability to detect prey (Aldridge 1986; Aldridge and Rautenbach 1987; Norberg and Rayner 1987). Some species are highly manoeuvrable and forage in physically cluttered environments; other species that are capable of fast direct flights hunt in open environments (Aldridge 1986; Aldridge and Rautenbach 1987; Brigham et al. 1997*a*). Open environments often support a greater diversity of bat species than do cluttered environments because bats are not flight restricted in open areas (Aldridge and Brigham 1991).

Big Brown Bats (*Eptesicus fuscus*) forage above tree-top level and may fly and forage up to 25 km away from the day-roost before returning before dawn (Wilkinson and Barclay 1997). Photo: Dr. Brock Fenton, University of Western Ontario.

Prey availability may have the strongest influence on foraging habitat selection (Fenton 1990). Proximity of suitable roosting sites (Cross 1988) and availability of water may also influence foraging habitat choice, especially for lactating female bats (Lacki et al. 2007; Adams and Hayes 2008; Adams 2010; Rainho and Palmeirin 2011).

Generally, insect species richness is positively correlated with plant community species richness (Panzer and Schwartz 1998; Kocher and Williams 2000). Diverse assemblages of vegetation, including broad-leaved herbs, shrubs, and trees (especially broad-leaved trees, such as cottonwoods) (Jamieson et al. 2001), are important hosts for moths in riparian and upland habitats. Kocher and Williams (2000) found species richness and diversity of North American Lepidopterans were lower in more disturbed habitats, and concluded that greater habitat diversity supported a greater number of Lepidopteran species.

In general, foraging habitat for bats can be divided into natural upland areas (e.g., forests, scrubland, grassland), lowlands (e.g., riparian, wetlands, ponds, lakes, and rivers), and urban habitats.

4.2.1 Upland Foraging Habitat

Upland foraging habitats include pastures (which are used by Townsend's Big-eared Bat), grasslands (used by Pallid Bat), old fields, shrublands, rights-of-way, and treed habitats (both coniferous and deciduous) (Nagorsen and Brigham 1993; Doucett et al. 2002). Some species forage at the base of cliffs, along benches, and at cliff tops (e.g., Western Small-footed Myotis). Species that use upland foraging areas may also use riparian areas as drinking and/or foraging habitats (Nagorsen and Brigham 1993).

Hardwood stands are important components of upland habitats because they provide potential roost sites and invertebrate prey. These forest types have fewer defences against insect herbivory and therefore support greater insect populations than do conifer forests (Jamieson et al. (2001). A wide variety of herbivorous insects use hardwoods, especially Lepidopteran (butterflies and moths) and Coleopteran (beetles) defoliators (Jamieson et al. 2001). In Canada, more than 300 species of insects live in aspen stands (Whitham et al. 1996). Moths and beetles are an important part of the diet of a number of bat species in British Columbia.

Small forest stands with diverse tree species, a rich understory, and adjacent vegetation can support moth communities that are as abundant and rich as large, uniform forest stands because they provide habitat for larvae that are dependent on herbaceous plants (Summerville and Crist 2004). Consequently, small, diverse stands may provide suitable foraging habitat for bats if they support suitable moth prey.

Grasses are not as productive for moths as are other forms of vegetation (Burford et al. 1999). Conversion of more complex habitat such as shrublands and forests to agricultural grasslands or croplands may significantly alter the abundance and community structure of moths and other insects (Burford et al. 1999). Overgrazing, fire, and purposeful manipulation (through chemical or mechanical methods) can also affect vegetation structure, although research has suggested that bat foraging behaviour is unaffected after a fire (Buchalski et al. 2013). Fire, mowing, and grazing regimes can affect insect productivity, which usually changes the insect community composition and may permanently alter the insect species that are present depending on the availability of post-prescription insect survivors and/or colonizers (Swengel 2001). Research on the Lepidopteran response to grassland management indicates that butterflies did not consistently favour one prescription type (i.e., fire, mowing or grazing) over another (Swengel 2001).

4.2.2 Lowland Foraging and Drinking Habitat

Forested riparian areas provide important foraging, drinking, commuting and roosting habitat for many bat species (Lunde and Harestad 1986; Cross 1988; Brigham et al. 1992; Brigham 1995; Grindal 1998) more so than non-forested riparian areas because of the protective cover from predators offered by the shadows cast by trees and shrubs (Rydell et al. 1996), as well as the abundance of insect prey (Fukui et al. 2006). Water temperature and quality, oxygen saturation, and sedimentation can affect insect production, and subsequently the quality and quantity of bat foraging habitat. The combination of low clutter of vegetation and high prey availability in riparian habitats (Mackey and Barclay 1989) likely makes them important to foraging bats (Lunde and Harestad 1986; Furlonger et al. 1987; Cross 1988; Brigham et al. 1992; Grindal 1995, 1998; Holloway and Barclay 2000; Seidman and Zabel 2001).

Open water may provide critical habitat for bats (Christy and West 1993; Bell 1980; Adams 2010). Sources of accessible (i.e., uncluttered areas where bats can make straight flights), non-contaminated drinking water are especially important to reproductive female bats, particularly during lactation (Adams 2010). Where water sources are limited or seasonally affected by drought, reproductive success may be lower because the lack of water can reduce the mother's ability to produce milk (Adams 2010).

Bats prefer calm slow moving water (von Frenckell and Barclay 1987; Mackey and Barclay 1989). Noise from fast-moving water interferes with bat echolocation; the use of "noisy" areas with rapids and waterfalls for foraging is low (von Frenckell and Barclay 1987; Mackey and Barclay 1989), although these features may be used as a navigational aid.

Lacustrine, palustrine, and riverine habitats are important to bats for foraging, commuting, and roosting (Krusic et al. 1996; Krusic and Neefus 1996; Parker et al. 1996; Sasse and Pekins 1996; Adams 2010). Streams typically have greater prey biomass than forests, and the insect community tends to be dominated by small- and medium-bodied insects (Thomas 1988) that are found in the diets of many bat species (Table 3). Riparian habitats are especially important for foraging females and volant young because the forested riparian area provides cover from dusk-flying predators, such as owls (Grindal et al. 1999). Reproductive females favour lower elevation riparian areas, likely because they provide rich insect prey resources and drinking water (Grindal et al 1999). Across the landscape, bats need a variety of riparian and wetland types with different sizes of water bodies in forested and non-forested locations (Doucett et al. 2002); even small ponds of less than 0.2 ha in open habitats can be important for some species (Ciechanowski 2002).

Uncluttered still water provides both foraging and drinking habitat for bats. Photo: Jennifer Gleason.

Some species, such as Northern Myotis, prefer to forage over water within forested stands (Thomas 1988; Holloway and Barclay 2000; Seidman and Zabel 2001; Doucett et al. 2002; Broders et al. 2006); however, males and females of this species may use different habitat types for foraging (Broders et al. 2006). Bat captures in non-riparian and upland habitats were biased towards male bats (Grindal et al. 1999). Wilkinson and Barclay (1997) suggested that females may defend prey-rich riparian areas, which can force male bats into non-riparian and upland habitats.

4.2.3 Urban Areas as Foraging and Drinking Habitat

Foraging and drinking habitat for some bat species is present in urban areas and these areas are of even higher value when suitable roosting habitat is available nearby. Bats forage on rich patches of insect prey around street lamps (Hickey and Fenton 1990; Rydell and Racey 1995). Urban parks can be important foraging and drinking habitat for bats (Kurta and Teramino 1992), especially if large trees and buildings nearby also provide roosting habitat (Evelyn et al. 2004).

Urban areas are most often situated in warm valley bottoms and near rivers and lakes, which is the same habitat favoured by breeding bats. However, habitat quality in urban areas may be degraded for bats. Urban landscapes have only 13% of the average net primary productivity of the original forested ecosystem (Schaefer 2003). Wetlands in urban settings are likely to be contaminated by storm-water runoff that picks up chemicals from roads, pesticide use in gardens, and other urban chemical pollution sources. Draining wetlands and diverting waterways may significantly impact foraging opportunities for bats. Use of insecticides in urban settings may further reduce prey availability for bats.

Coleman and Barclay (2011) found that Little Brown Myotis in urban areas were not as reproductively successful as those in more natural areas. This might be due to poor habitat quality in urban areas and possibly because of increased competition among individuals in large colonies in urban areas. Colonies in buildings in urban areas were larger than colonies in non-urban settings (Coleman and Barclay 2011), potentially due to limited roosting opportunities in urban areas, which concentrate the population in limited roost sites.

4.3 Spatial Use of Habitat and Area Requirements

Effective management of bat populations depends not only on understanding the distribution of specialized and limited habitats for bats, such as roosting and foraging habitats, but also the connectivity between these habitats, and the seasonal changes in the use of these habitats. Understanding movement patterns of bats is challenging given their cryptic habits, small size, nocturnal activity patterns, and potential for conducting long distance flights.

Proximity of different habitat types is important for bats (Findley 1993). Flight can be 10 times more energetically expensive than roosting (Kurta et al. 1987; Barclay 1989). The farther a roost is from a foraging area, the greater the energetic costs are to the bats (Keinath 2003), and the point at which this distance becomes energy-prohibitive for a given species of bat depends on the life-stage (such as non-reproductive female, lactating female), sex, and age of the individuals; habitat structure; forage quality; and availability of water (Keinath 2003). Bat species diversity is highest and population size is largest in areas where habitat requirements for all seasons (summer roosting and foraging, fall swarming, winter hibernation) are available in close proximity (Findlay 1993). The definition of "close proximity" depends on the bat species. Based on the foraging distances of reproductive female bats in British Columbia, the 16 bat species can be classified into three groups: short-range, mid-range, and long-range flyers (Table 7). A detailed literature review of foraging travel distances and flight heights for bats species in British Columbia is provided in Appendix A.

Small Myotis species tend to make shorter foraging flights (1–2 km) away from day-roosts. Photo: Dr. Brock Fenton.

Straight-line estimates of maximum distances travelled are useful in evaluating conservation needs of bat colonies and can be valuable for indexing habitat requirements, especially when management and conservation decisions must be made quickly and data on local habitat use by bats would take too long to collect and analyse (Lacki et al. 2007).

Table 7. Classification of British Columbia's 16 bat species into short-, mid-, and long-range flyers based on measured distances flown between maternity sites and foraging areas, and/or distances flown between capture site and subsequent day-roost.

Short-range flyers (generally 1 kilometre or less, but can range up to 5 or 6 kilometres)	
8 species	Western-small Footed Myotis, California Myotis Long-eared Myotis Keen's Myotis Northern Myotis Fringed Myotis Long-legged Myotis Pallid Bat
Mid-range flyers (always more than 2 kilometres but generally around 5–8 kilometres)	
4 species	Little Brown Myotis Yuma Myotis Red Bat Townsend's Big-eared Bat
Long-range flyers (generally 10 kilometres or more)	
4 species	Hoary Bat Big Brown Bat Spotted Bat Silver-haired Bat

Flying Little Brown Myotis (*Myotis lucifugus*). Photo: Dr. Brock Fenton.

Recent conservation management for the Indiana Bat (*Myotis sodalis*) in the U.S. has used information on the distances travelled between capture and subsequent day-roost, distances flown between successive day-roosts, and distances travelled from the day-roost during nightly foraging bouts to estimate an index of home range size for bats (USFWS 2011). These distances are used to calculate home range as the area of a circle with the centre point based on the day-roost or roosts, or hibernation site, which is useful when no other data are available. However, limitations to this approach need to be considered when making management recommendations on a site-specific basis.

Home range sizes for bats can vary significantly between males, non-reproductive females, reproductive females, adults, and juveniles (Lacki et al.

2007). There can also be significant variation in home range size within a species from early in the reproductive season to late in the reproductive season (Lacki et al. 2007). Bats in coastal British Columbia exhibited higher commuting activity between roosting and foraging areas within riparian habitat (lakes and creeks) than other habitat types, such as interior forest, cutblock edges, and roads (Grindal 1998).

Most of British Columbia's bat species use more than one day-roost location during the summer; many species use a series of day-roosts in a "roost-area" (Vonhof and Barclay 1997; Barclay and Kurta 2007). Radio-telemetry work has identified distances moved between successive roosts by some species, and some studies have calculated roost area sizes (Barclay and Kurta 2007). Many species switch roosts repeatedly (Brigham 1991; Lewis 1995; Vonhof and Barclay 1996; Rabe et al. 1998, but see Willis et al. 2003) but show fidelity to forest patches where those roost are located (e.g., Little Brown Myotis [Kalcounis and Hecker 1996]; Long-legged Myotis [Ormsbee 1996]; Red Bat [Hutchinson and Lacki 2000]; Big Brown Bat, Hoary Bat, Californian Myotis, and Long-eared Myotis [Vonhof and Gwilliam 2000]; Fringed Myotis [Weller and Zabel 2001; Swier 2003]). Vonhof and Gwilliam (2000) reported movement distances of 5 m to 1.6 kilometres between day-roosts; Hutchinson and Lacki (2000) reported that roosts were within an area < 40 m^2; Ormsbee (1996) reported average distances between roosts of 412.5 m for 11 individual bats, and 3.7 kilometres for one individual bat. Distance moved is likely influenced by the density of the required habitat element (in this case, suitable roost trees). The roost switching/patch site fidelity behaviour of bats has implications for designating minimum patch size.

In addition to proximity, connectivity between roosting and foraging habitat is important for many species (Racey and Entwistle 2003; Lacki et al. 2007; Henderson and Broders 2008). Bats frequently commute between roosts and foraging areas along linear features (Verboom and Huitema 1997).

Migration corridors and seasonal movements between summer and winter habitats are even less known in British Columbia. In Ontario, Silver-haired Bats have been observed setting out to cross Lake Erie during fall migration, which is a minimum distance of 38 kilometres (McGuire et al. 2012). Smaller species are also known to make large movements between seasons: Little Brown Myotis in Ontario have been documented moving nearly 200 kilometres between winter and summer habitats (Fenton 1969). There may also be considerable movement and site switching during the winter hibernation period in some parts of British Columbia, a phenomenon that is only beginning to be understood (C. Lausen, pers. comm.). This makes it challenging to identify habitat elements that are necessary for maintaining connectivity between summer and winter habitats.

Section 5: Existing and Emerging Threats

Bats are particularly sensitive to existing and emerging threats because a slow reproductive rate (one or two pups a year), long lifespan, and habit of coloniality make bat populations vulnerable to extirpations. Colonial species are especially vulnerable to extirpation because a single negative event can impact an entire local population of one or even multiple species. The removal or disruption of a colony made up entirely of breeding females and their pups (sometimes mixed species) or a hibernaculum that contains all members from a large area (sometimes mixed species) could have a significant effect on the population in a large area.

The primary threats to bats and their habitats in British Columbia from various resource industries and human-related activities include direct mortality, habitat loss and degradation, habitat fragmentation, pesticide use, White-nose Syndrome, and climate change. In the next chapters (Table of contents on page 7 of this document) we discuss potential impacts from specific industries such as wind energy development, mining etc. So these industry-specific threats are not mentioned in the list below which is not intended to be a complete list of potential threats faced by bats. The discussion below is only a short summary of generic threats and global threats such as emerging disease and climate change.

5.1 Habitat Loss and Degradation

The stability of a bat population depends on the continued presence of required roost types (e.g., summer, winter, day, night, maternity, and swarming), adequate and diverse foraging habitats, and connectivity between these habitats. Habitat could be lost due to timber harvesting, clearing of forested lands for urban development, or other forms of resource development. The failure to recruit appropriate age class/size/decay class of trees (Maser et al 1979) for future roosting habitat will have long-term effects on bat populations if alternative, effective roosting habitat is not available. Loss of hibernation sites, either from the closure of mine adits that are used by bats or from human disturbance at caves or mines, will also affect bat populations. Sometimes, the effectiveness of roost and hibernation sites may depend on the integrity of multiple features. For example, it is now known that Silver-haired Bats move between mine/crevice hibernacula and nearby trees/snags (Lausen and Hill 2016) during the winter hibernation period. It is possible that value of some hibernation areas could be degraded or lost by the removal of one feature (e.g., trees) even while another feature (e.g., mine) could remain intact. Loss of foraging and drinking habitat can result from land reclamation (draining wetlands), channelization and loss of riparian habitats, and contamination and sedimentation of wetlands, ponds, and riparian habitats.

Logging along streams in western Oregon resulted in decreased bat activity along the riparian strip; bat activity, on average, was 4.1–7.7 times higher in wooded riparian areas than in adjacent clearcuts (Hayes and Adam 1996). Riparian management prescriptions, such as buffers, may not fully protect bat habitat. Harvesting near a stream, even when buffers are maintained (up to 74 m) or various variable retention treatments are used, causes changes within the stream microclimate, which include increased temperature and reduced humidity (Chen et al. 1999; Macdonald et al. 2003). These changes in micro-environment can cause changes in vegetation (Chen et al. 1999) and, potentially, insect abundance or diversity (Hayes and Adam 1996).

Even in urban and rural areas, where bats have adapted to human modified environments newer developments may result in loss of bat habitats. Older buildings and abandoned structures may provide important summer roosting habitat for bats. Older structures are being removed from the landscape, and replacement structures are often built with no access for bats. Rural structures such as barns and lakeside cabins are often favoured roost sites. Loss of this roosting habitat could be critical for some species in some parts of British Columbia.

Currently, knowledge of the location of summer and winter roosting habitat, current and historic patterns of use by bats is very limited in British Columbia, making it difficult for land managers to make decisions that are favourable to bat conservation and bat habitat protection.

5.2 Habitat Fragmentation

Habitat selection by bats is influenced by the spatial arrangement of required elements, including day-roosts, night-roosts, hibernacula, foraging areas, and access to water. Many human-related activities and developments in B.C. contribute to habitat fragmentation, including forestry, transportation networks, urban development, and networks of rights-of-way associated with power lines and industries, such as oil and gas pipelines and associated infrastructure. Habitat fragmentation may result in required habitat elements being farther apart on the landscape, and in the reduced occurrence of some bat species (Ekman and de Jong 1996; Walsh and Harris 1996). Some bat species avoid crossing large open areas. They may travel significant distances to circumnavigate open areas rather than cross an open space by the most direct route (Entwistle et al. 2001). Some bat species may not fly across gaps wider than 10 m (e.g., rights-of-way, gaps in hedgerows bordering fields, gaps in forested riparian edges [Entwistle et al. 2001]). Consequently, fragmentation could make habitats unsuitable and inaccessible for these species (Limpens and Kapteyn 1991).

Isolated forest patches more than 100 m from a large tract of contiguous forest may have fewer foraging bats due to a lack of habitat connectivity and the tendency of some species to avoid flying over open spaces (Swystun et al. 2001). Fragmentation that creates progressively smaller patches of suitable habitat in a matrix of unsuitable or less suitable habitat could produce habitat patches that are too small to maintain bat populations. Windthrow is higher along edge habitats, which might result in loss of roost habitat (Ruell 2000). Bats that roost along edges may experience a higher predation risk; in interior forest, bats are less visible, and there are fewer predators (Hutchinson and Lacki 2000).

Gleaning species, such as the Long-eared Myotis (*M. septentrionalis, M. evotis,* and *M. keenii),* are well suited to foraging in forest habitat and seem to prefer forested habitat rather than forest openings (Caire et al. 1979; Fitch and Shump 1979; Thomas 1988; Faure et al. 1993; Jung et al. 1999; Doucett et al. 2002; Owen and Menzel 2003). Forest removal affects microclimate at both the stand- and landscape-scale (Chen et al. 1999). Temperatures within contiguous forests are cooler during the day but are warmer at night, and they are less variable than in openings (Chen et al. 1999). In addition, forest stands have lower wind speeds and higher humidity than do clearcuts (Chen et al. 1999). Edge effects of openings may extend approximately 50 m (Kremsater and Bunnell 1999) and up to 400 m (Chen et al. 1999) into the adjacent forest stand.

Fragmentation might not be entirely detrimental to bats. Some species make take advantage of better microclimates (e.g., warmer) in roosts along forest edges (Waldien et al. 2000). Edge habitat created by gaps in the canopy due to harvesting or road construction may produce favourable roosting habitat for bats (Ormsbee 1996) by increasing solar radiation and ease of access to roosts (Waldien et al. 2000). Removal of the forest canopy may also improve, at least temporarily, the suitability of rocky outcrops or caves (for crevice or cave-roosting bats) that might previously have been too cool.

For bat species that prefer fast, direct flights in open habitats (e.g., Big Brown bats and Silver-haired bats), forest fragmentation that results from the creation of roads and trails, or rights-of-way may create foraging and commuting habitat by increasing edge habitat (DeJong 1994; Crampton and Barclay 1996; Grindal and Brigham 1998; Verboom and Spoelstra 1999). Bat may fly along protected lines of vegetation in order to exploit insect prey that is distributed along tree lines and hedgerows. Bats may simply be following prey along edges rather than flying out into open areas (with no or low levels of flying insects).

Some linear features, such as tree lines, hedgerows, and riparian habitats (i.e., overgrown banks, edges of water courses and lakes, ditches), often produce abundant insect prey for foraging bats (Entwistle et al. 2001). Edge habitat may be associated with more diverse insect assemblages than is the forest interior or open areas (Verboom and Spoelstra 1999; although see Grindal and Brigham [1998]). Linear edge habitats such as hedgerows that connect larger patches of more favourable habitats may also provide a more sheltered flight path from wind or a safer travel route to avoid predators than open habitat or it may serve as a navigational aid to bats at the landscape level (Limpens and Kapteyn 1991; Grindal and Brigham 1998; Verboom and Spoelstra 1999). Estrada and Coates-Estrada (2001) termed these linking edge habitats as "live fences," and described the valuable forest patches as "stepping-stones" where otherwise fragmentation may create large expanses of unsuitable habitat.

Powerline right-of-way through forested land in southern British Columbia. Photo: Susan Holroyd.

5.3 Pesticide Use

Pesticide use may cause reductions in populations of insects that occur in the diet of bats in British Columbia. Pesticide use is common in agriculture, forestry, urban areas (including the control of insects and roadside vegetation), and hydroelectric developments (to control vegetation in power line rights-of-way). Pesticide spraying for agricultural and residential use can lead to toxic effects on Little Brown Myotis, Townsend's Big-eared Bat, and other bat species (Anthony and Kunz 1977; Kunz et al. 1977; Clark et al. 1978; Fenton and Barclay 1980). In addition, the dumping of non-source pollutants, such as PCBs, cyanide, or mercury, can have toxic effects on Little Brown Myotis and other bat species and their prey (Fenton and Barclay 1980; Driscoll et al. 2007; Kunz and Reichard 2010). Pesticides accumulate in the fat tissue of bats (Fenton 1983), and cross the placenta into developing embryos (Thies and McBee 1994). The effects of pesticides may be strongest on the weakest and youngest bats, which rely most heavily on stored fat reserves (Fenton 1983).

Even organically certified pesticides, such as Btk (*Bacillus thuringiensis* var. *kurstaki*) formulations, kill non-target Lepidoptera (moths and butterflies) (Miller 2000) and could affect the prey base of bats. Pesticides are used in forests in British Columbia to control insect pests. In British Columbia, spraying of Btk in forests increased from 2200 ha in 1988 to more than 21,000 ha in 2001 (CCFM 2003). More recent data on current usage levels is not publically available. Abundance of Lepidoptera species declined by 80–100%, and live caterpillar mass declined by 84–99% following the aerial application of Btk (Miller 2000). Although substantial recovery occurred after three years, there was no evidence that a complete recovery of all species had occurred (Miller 2000).

Bats in a hibernation site exhibiting tell-tale signs of White-nose Syndrome. Indiana bats (*Myotis sodalis*), New York State. Photo: Al Hicks.

Herbicides and other land management treatments that change the vegetation cover of an area may also cause changes in insect communities and/or population levels, which could affect forage availability for bats.

5.4 White-nose Syndrome

White-nose syndrome is a lethal fungal disease that is spreading rapidly through populations of North America's hibernating bat species. Unprecedented levels of bat mortality have been recorded in eastern North American since 2006, when a fungal pathogen *Pseudogymnoascus* (*Geomyces*) *destructans* (Gargas et al. 2009; Minnis and Lindner 2013) was observed on the noses and tail and wing membranes of hibernating bats of various species. As of February 2014, more than 6-7 million bats from nine species had died from this fungal infection (https://www.whitenosesyndrome.org/).

White-nose Syndrome has been spreading throughout eastern U.S. and Canada since it was first observed in New York in the winter of 2006-2007. It has spread to 23 U.S. states as far west as Illinois, and five Canadian provinces (USFWS 2013). In winter 2009–2010, the disease was discovered in Ontario (Ontario MNR 2013) and Quebec in 2010 (Quebec MNRF 2010); it was documented in Nova Scotia and New Brunswick in 2011 (Nova Scotia DNR 2011; New Brunswick DNR 2011) and in 2013 it was recorded in Prince Edward Island (Prince Edward Island DAF 2013). The disease is estimated to reach the west coast of North America between 2017 and 2027 (Kunz 2009; Ihlo 2013). Transmission of the fungal spores is likely from bat-to-bat; however, initial introduction and further transmission is also likely due to anthropogenic sources. Monitoring is ongoing, but extirpations of populations are likely, and extinctions of some species are possible. *Pseudogymnoascus* (*Geomyces*) *destructans* has also been found in Europe (Puechmaille et al. 2010; Minnis and Lindner 2013); however, unlike North America, it does not appear to be associated with bat deaths.

Bats with White-nose Syndrome have little to no fat reserves, and may exhibit abnormal behaviour, such as moving closer to the entrance of their hibernation site, or exiting and flying around during the day. Many bats have been found dead inside and outside the cave. A current theory as to why the disease is so devastating to bats involves bat hibernation physiology. During hibernation, bat body temperature, metabolic rate, and immune response are all depressed. Body temperature and metabolic rate drop to save energy; immune response drops as a result of the drop in the first two conditions. Fungal spores living in cold cave environments attack the bats, and the fungus flourishes because the hibernating bats' immune responses are depressed. When the bats finally wake as a result of the infection, they become active mid-winter and are without food resources. Warming up and flying uses up valuable fat resources and results in bats starving to death. Other physiological imbalances resulting from the disease are also associated with mortality (Verant et al. 2014). Disruption of water balance due to wing tissue destruction, which results in dehydration, has also been implicated in White-nose Syndrome mortalities (Wilcox et al. 2013). Survival of bat species will depend on the long-term response of bats to the fungal pathogen; a long slow recovery is possible if bats develop some kind of immunity to the infection (Throgmartin et al. 2013). This wildlife pandemic represents the single largest known wildlife health crisis on the North American continent to date. Research is ongoing on potential mitigation strategies (e.g., Cornelison et al. 2014); adaptive management is the key to controlling the spread of the disease and mitigating its impacts.

5.5 Climate Change

Predicted climate change effects for much of western North America include extreme weather patterns, especially drought but also extreme heat, cold, and precipitation; increasing storm intensities; and sea level rise (Jones et al. 2009; Adams 2010). Levels of bat activity and bat numbers may change with these climate effects (Jones et al. 2009).

Bats, especially lactating females, appear to be very sensitive to the availability of water resources for drinking. A lack of water resources can cause a decline in bat reproductive success and a drop in numbers (Adams 2010). Even a diminished water output from a small stream may impact a local bat population (Adams 2010). Bats in dry regions of Europe fly long distances to find water, which explains why their home ranges are so large (Rainho and Palmeirin 2011); drought conditions brought on by climate change may force bats to fly even farther. In areas where climate change reduces water availability, reproductive success may be significantly diminished (Adams 2010).

Bat reproduction and hibernation are both closely tied to environmental temperatures and conditions. Timing of behaviours such as entering hibernation in autumn and emergence in spring (with subsequent initiation of pregnancy) occurs only when they are cued by temperature and weather. Consequently, there may be measureable changes in bat populations and the timing of their behaviours as a result of climate change.

Adams (2010) predicts that because bats are sensitive to environmental change, they will act as early warning indicators of the large-scale ecological effects of climate change, especially in western North America. Jones et al. (2009) advocate for the implementation of a global network for monitoring bat populations allowing the use of bats as bio-indicators of ecosystem changes around the planet.

Section 6: Glossary

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

Adit: a horizontal mine passage driven from the surface (Thomson 2002).

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

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

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

Blind: a mine passage without lateral workings (Thomson 2002).

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

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

Curtailment: limiting the supply of electricity during conditions when it would normally be supplied. Accomplished by cutting-out the generator from the grid and/or feathering the turbine blades (from Arnett et al. 2013).

Cut-in speed: the wind speed at which the turbines produce electricity. Some turbine blades will continue to spin even when no electricity is produced (adapted from Arnett et al. 2013).

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

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

Ephemeral roost: a bat roost in a feature where the characteristics important to bats (e.g., microclimate) may change quickly and/or unpredictably. For example, a roost might be found in an area under sloughing tree bark.

Feathering of the blades: adjusting the angle of the rotor blade parallel to the wind, or turning the whole unit out of the wind to slow or stop blade rotation (from Arnett et al. 2013).

Fertilization: the impregnation of the egg by the male sperm cell (Nagorsen and Brigham 1993).

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

Forage: to hunt for food.

Gestation period: the length of a pregnancy; the time from fertilization until the birth of the fetus (Nagorsen and Brigham 1993).

Gleaner: a bat that can capture prey on the leaves and twigs of vegetation or on the ground (Nagorsen and Brigham 1993).

Goal: Goals provide general purpose and direction. They are the end result of ultimate accomplishment toward which an effort is directed. They generally should reflect perceived present and future need. They must be capable of being effectively pursued (B.C. Ministry of Forests 2008). An ideal; a desired endpoint; frequently defined in abstract terms. Goals are qualitative and are achieved by means of objectives (Dunster and Dunster 1996).

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

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

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

Hibernation: a state of lethargy characterized by a reduction in body temperature and metabolic rate (Nagorsen and Brigham 1993).

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

Inventory: a single enumeration of an ecological system; generally carried either as a basis for estimating potential yield or to establish a benchmark. An inventory may act as one point in time in a monitoring program. Ecological inventories may be more comprehensive and spatially/temporally discrete than monitoring activities (Quayle 2003).

Lactation: the period of milk production by female mammals nursing young (RISC 1998).

Lacustrine: living or growing in or along the edges of lakes.

Landscape Unit: an area of land and water used for long-term planning of resource management activities. It is important for designing strategies and patterns for landscape-level biodiversity and for managing other forest resources (British Columbia MOF and British Columbia MELP 1999).

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

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

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

Monitoring: repeated, systematic measurements done with a specific purpose in mind. Monitoring is focused on measurements over time in order to detect the change toward, or away from, a stated standard or objective. Monitoring is part of the cycle of assessment and evaluation that is linked to management activities (Quayle 2003).

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

Nearshore wind development: one built on land within 3 kilometres of a coastline, or in the ocean < 10 kilometres from land (see offshore and onshore developments).

Nocturnal: active at night.

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

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

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

Objective: a quantifiable, measurable and defined target, capable of attainment within a defined period of time. Objectives are the means by which goals are achieved and should include four main components: 1) they must state the desired outcome (i.e., what is to be accomplished); 2) they must indicate the time period within which the expected outcome is to be achieved; 3) they must include measurement factors, such as quantity, quality, or cost, so that the fulfilment of the objective can be verified; 4) they must indicate who is responsible for achieving the indicated result. Desirable (but not absolutely essential) elements of objectives are a description of how they will be achieved and an indication of who will determine whether the results have been achieved. Objectives are typically narrower and shorter in range than goals, and serve as milestones toward goal achievement (Dunster and Dunster 1996).

Offshore wind development: one built in the ocean ≥ 10 kilometres from land (see onshore and nearshore developments).

Onshore wind development: one built on land > 3 kilometres from a coastline (see nearshore and offshore developments).

Ovulation: maturation and release of the egg before fertilization.

Palustrine: living or growing in or along the edges of swamps, marshes or wetlands.

Parturition: birth.

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

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

Pup: a bat born during the current year.

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

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

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

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

Riverine: living or growing in or along the edges of rivers.

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

Shaft: a vertical mine opening from the surface (Thomson 2002) may also apply to cave systems.

Significant bat roost:

- any hibernaculum or swarming site;
- a roost used by a nursery colony of a Red- or Blue-listed species (any number of individuals), or a nursery roost used by more than six females of other species (can include mixed species groups);
- a roost used by a maternity colony of Red- or Blue-listed species (any number of bats), or a maternity roost used by more than four females of other species (can include mixed species groups);
- any permanent type day-roost used by a male or a non-reproductive female of a Red- or Blue-listed species, or > 10 males/non-reproductive females/juveniles of other species (can include mixed species groups);
- any night-roost used by a Red- or Blue-listed species or > 10 bats of other species (can include mixed species groups);
- any regularly used roost of a species listed under Schedule 1 of the *Species at Risk Act* (any number of individuals); or
- any other roost deemed significant by an experienced bat biologist.

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

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

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

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

Tunnel: a horizontal mine passage that is open at both ends (Thomson 2002).

Volant: capable of flying.

Winze: a mine opening sunk downward from inside to connect lower levels or explore areas beneath a level (Thomson 2002).

Yearling: a bat born in the previous reproductive year.

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

Section 7: Additional Information

Contacts for Ministry biologists

For information on bats or other species at risk in British Columbia, contact:

Purnima Govindarajulu, Ph.D.
Small Mammal and Herpetofauna Specialist
Ecosystems Branch, Wildlife Science Section
B.C. Ministry of Environment
PO Box 9338 Stn Prov Govt
Victoria, B.C. V8W 9M1 Canada
Telephone: (250) 387-9755
Fax: (250) 356-9145
Email: Purnima.Govindarajulu@gov.bc.ca

Ministry of Environment – Lower Mainland office
10470 - 152nd St.
Surrey, B.C. V3R 0Y3
Tel: (604) 582-5200
Fax: (604) 930-7119

Ministry of Environment – Vancouver Island office
2080-A Labieux Rd.
Nanaimo, B.C. V9T 6J9
Tel: (250) 751-3100
Fax: (250) 751-3103

Ministry of Environment – Thompson Region
1259 Dalhousie Dr.
Kamloops, B.C. V2C 5Z5
Phone (250) 371-6200
Fax: (250) 828-4000

Ministry of Environment – Kootenay Region
Environmental Protection office
205 Industrial Rd. G
Cranbrook, B.C. V1C 7G5
Phone: (250) 489-8540
Fax: (250) 489-8506

Ministry of Environment – Cariboo Region
400 - 640 Borland St.
Williams Lake, B.C. V2G 4T1
Phone: (250) 398-4530
Fax: (250) 398-4214

Ministry of Environment – Skeena Region
3726 Alfred St.
Bag 5000
Smithers, B.C. V0J 2N0
Phone: (250) 847-7260
Fax: (250) 847-7591

Ministry of Environment – Omineca Region
#325 - 1011 4th Ave.
Prince George, B.C. V2L 3H9
Phone: (250) 565-6135
Fax: (250) 565-6629

Ministry of Environment – Okanagan Region
102 Industrial Pl.
Penticton, B.C. V2A 7C8
Phone: (250) 490-8200
Fax: (250) 490-2231

Ministry of Environment – Peace Region
Room 400, 10003 - 110th Ave.
Fort St. John, B.C. V1J 6M7
Phone: (250) 787-3411
Fax: (250) 787-3490

Links to Additional Information

- Regions of British Columbia
- Copies of all official legislation for the Province of British Columbia is available online.
- Ministry of Environment Guidelines and Best Management Practices for environmental stewardship

Additional Information on Bats

- The Species and Ecosystems Explorer provides information on all the species of bats in the province of British Columbia.
- Bat Conservation International has information about bat species, bat gating, and bat houses.
- The Community Bat Programs of British Columbia help homeowners with bats and provides opportunity for property owners to be involved in bat research. An excellent resource when managing bats in buildings.
- British Columbia Bat Action Team (BCBAT, a bat conservation group)
- For the latest information on White-nose Syndrome, see the Canadian Wildlife Health Cooperative as well as British Columbia Ministry of Environment's Wildlife Health website. The US Fish and Wildlife Service also provides the latest information on the spread of White-nose Syndrome across North America as well as up-to-date information on White-nose Syndrome research.
- The Wildlife Conservation Society of Canada has launched a program to help cavers understand and help with bat conservation. BatCaver.org can be found at http://programs.wcs.org/batcaver/Home.aspx

Section 8: References

Adam, M.D., and J.P. Hayes. 2000. Use of bridges as night roosts by bats in the Oregon Coast Range. Journal of Mammalogy 81(2):402-407.

Adams, R.A., and M.A. Hayes. 2008. Water availability and successful lactation by bats as related to climate change in arid regions of western North America. Journal of Animal Ecology 77:1115-1121.

Adams, R.A. 2010. Bat reproduction declines when conditions mimic climate change projections for western North America. Ecology 91:2437-2445.

Aldridge, H. 1986. Manoeuverability and ecological segregation in the Little Brown (*Myotis lucifugus*) and Yuma (*M. yumanensis*) Bats (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 64:1878-1882.

Aldridge, H.D.J.N., and R.M. Brigham. 1991. Factors influencing foraging time in two aerial insectivores: the bird *Chordeiles minor* and the bat *Eptesicus fuscus*. Canadian Journal of Zoology 69(1):62-69.

Aldridge, H.D.J.N., and I.L. Rautenbach. 1987. Morphology, echolocation and resource partitioning in insectivorous bats. Journal of Animal Ecology 56:763-778.

Anthony, E.L.P., and T.H. Kunz. 1977. Feeding strategies of the Little Brown Bat, *Myotis lucifugus*, in southern New Hampshire. Ecology 58:775-786.

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

Arnett, E.B., G.D. Johnson, W.P. Erickson, and C.D. Hein. 2013. A synthesis of operational mitigation studies to reduce bat fatalities at wind energy facilities in North America. A report submitted to the National Renewable Energy Laboratory. Bat Conservation International. Austin, Texas, USA. 38pp.

Barchi, J.R., J.M. Knowles, and J.A. Simmons. 2012. Spatial memory and stereotype of flight paths by Big Brown Bats in cluttered surroundings. Journal of Experimental Biology 216:1053–1063. [http://www.popsci.com/science/article/2013-02/bats-build-internal-maps-their-surroundings-and-remember-them-future-flights]

Barclay, R.M.R. 1984. Observations on the migration, ecology and behavior of bats at Delta Marsh, Manitoba. Canadian Field-Naturalist 98:331-336.

Barclay, R.M.R. 1985. Long-versus short-range foraging strategies of Hoary (*Lasiurus cinereus*) and Silver-haired (*Lasionycteris noctivagans*) Bats and the consequences for prey selection. Canadian Journal of Zoology 63:2507-2515.

Barclay, R.M.R. 1986. The echolocation calls of Hoary (*Lasiurus cinereus*) and Silver-haired (*Lasionycteris noctivagans*) Bats as adaptations for long- versus short-range strategies and the consequences for prey selection. Canadian Journal of Zoology 64:2700-2705.

Barclay, R.M.R. 1989. Effect of reproductive condition on the foraging behavior of female Hoary Bats, *Lasiurus cinereus*. Behavioral Ecology and Sociobiology 24:31-37.

Barclay, R.M.R. 2012. Variable variation: annual and seasonal changes in offspring sex ratio in a bat. PloS ONE 7(5):e36344. [http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0036344]

Barclay, R.M.R., and R.M. Brigham. 2001. Year-to-year reuse of tree-roosts by California Bats (*Myotis californicus*) in southern British Columbia. American Midland Naturalist 146:80-85.

Barclay, R.M., P.A. Faure, and D.R. Farr. 1988. Roosting behavior and roost selection by migrating Silver-haired Bats (*Lasionycteris noctivagans*). Journal of Mammalogy 69:821-825.

Barclay, R.M.R., J.H. Fullard, and D.S. Jacobs. 1999. Variation in the echolocation calls of the Hoary Bat: influence of body size, habitat structure and geographic location. Canadian Journal of Zoology 77:530-534.

Barclay R.M., and L.D. Harder. 2003. Life histories of bats: life in the slow lane. Pp. 209–253 *in* T.H. Kunz and M.B. Fenton, eds. Bat ecology. University of Chicago Press, Chicago, IL. 779pp.

Barclay, R.M.R. and A. Kurta. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. Chapter 2. Pp. 17-59 *in* M.J. Lacki, J.P. Hayes and A. Kurta, eds. Bats in Forests: Conservation and Management. John Hopkins University Press. 329pp.

Bat Conservation International. 2014. Bats in buildings program. [http://batcon.org/ accessed March 2014].

Bat Conservation Trust. 2007. Bat surveys- Good practice guidelines. Bat Conservation Trust, London, UK. 82pp.

BC BATS. 2014a. Got Bats? British Columbia Bat Action Team, Bat Conservation Program. [http://www.bcbats.ca/ accessed January 2015].

BC BATS 2014b. Participate in Bat Watch: BC Bat Count. British Columbia Bat Action Team, Get Involved. [http://bcbats.ca/index.php/get-involved/participate-in-the-bc-bat-count accessed January 2015].

Bell, G.O. 1980. Habitat use and response to patches of prey by desert insectivorous bats. Canadian Journal of Zoology 58:1876-1878.

Belwood, J.J., and M.B. Fenton. 1976. Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 54:1674-1678.

Betts, B.J. 1996. Roosting behaviour of Silver-haired Bats (*Lasionycteris noctivagans*) and Big Brown Bats (*Eptesicus fuscus*) in northeast Oregon. Pp. 55–61 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions

Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Black, H.L. 1974. A north temperate bat community: structure and prey populations. Journal of Mammalogy 55:138-157.

Bogan, M.A., E.W. Valdez, and K.W. Navo. 1998*a*. *Myotis yumanensis*, Yuma Myotis. Species Accounts. Western Bat Working Group.[http://www.wbwg.org/]

Bogan, M.A., E.W. Valdez, and K.W. Navo. 1998*b*. *Myotis evotis*, Western Long-eared Myotis. Species Accounts. Western Bat Working Group. [http://www.wbwg.org/]

Boland, J. L., J. P. Hayes, W. P. Smith and M. M. Huso.2009. Selection of day-roosts by Keen's Myotis (*Myotis keenii*) at multiple spatial scales. Journal of Mammalogy 90:222-234.

Bolster, B.C. 1998. *Lasiurus cinereus,* Hoary Bat. Species Accounts. Western Bat Working Group.[http://www.wbwg.org/]

Bonar, R.L. 2000. Availability of pileated woodpecker cavities and use by other species. Journal of Wildlife Management 64:52-59.

Borkent, C., and L. Greenway. 1997. Sphinx moths (Family Sphingidae) in British Columbia: biological notes and field key, based on specimens in the collection at the Royal British Columbia Museum. Royal British Columbia Museum, Victoria, BC.

Boyles, J.G., P.M. Cryan, G.F. McCracken, and T.H. Kunz. 2011. Economic importance of bats in agriculture. Science 332(6025):41-42. [http://www.sciencemag.org/content/332/6025/41.short]

Brigham, R.M. 1991. Flexibility in foraging and roosting behaviour by the Big Brown Bat (*Eptesicus fuscus*).Canadian Journal of Zoology 69:117-121.

Brigham, R.M. 1995. Riparian habitat and its importance for roosting and foraging by insectivorous bats. Pp. 57-72 *in* K.H. Morgan and M.A. Lashmar, eds. Riparian habitat management and research: a special publication of the Fraser River Action Plan. Proceedings of a workshop sponsored by Environment Canada and the B.C. Forestry Continuing Studies Network, Kamloops, BC, 4–5 May 1993. Environment Canada – Canadian Wildlife Service.

Brigham, R.M. 2007. Bats in forests: what we know and what we need to know. Pp. 1–16 *in* M.J. Lacki, J.P. Hayes, and A. Kurta, eds. Bats in forests: conservation and management. John Hopkins University Press, Baltimore, MD.

Brigham, R.M., H.D.J.N. Aldridge, and R.L. Mackey. 1992. Variation in habitat use and prey selection by Yuma Bats (*Myotis yumanensis*). Journal of Mammalogy 73:640–645.

Brigham, R.M., S.D. Grindal, M.C. Firman, and J.L. Morissette. 1997*a*. The influence of structural clutter on activity patterns of insectivorous bats. Canadian Journal of Zoology 75:131–136.

Brigham, R.M., M.J. Vonhof, R.M.R. Barclay, and J.C. Gwilliam. 1997*b*. Roosting behavior and roost-site preferences of forest-dwelling California Bats (*Myotis californicus*). Journal of Mammalogy 78:1231–1239.

British Columbia Environmental Assessment Office (BC EAO). 2003. Summary guide to the British Columbia environmental assessment process. [http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/360560/brochure_mar_03.pdf]

B.C. Ministry of Environment. 2012. Procedures for mitigating impacts on environmental values (environmental mitigation procedures). Final working draft. Available here

B.C. Ministry of Environment. 2014a. Addressing cumulative effects in natural resource decision making: a framework for success. February. 2014. Available here.

B.C. Ministry of Environment. 2014b. Environmental Mitigation Policy latest update. May 2014. Available here.

British Columbia Ministry of Forests (BC MOF). 2003. Karst inventory standards and vulnerability assessment procedures for British Columbia. Version 2. Prepared for the Karst Task Force Resources Inventory Standards Committee, Province of British Columbia, Victoria, BC. 112pp. [http://www.for.gov.bc.ca/hts/risc/pubs/earthsci/karst_v2/karst_risc.pdf]

British Columbia Ministry of Forests (BC MOF). 2008. Glossary of forestry terms in British Columbia. Victoria, BC. [http://www.for.gov.bc.ca/hfd/library/documents/glossary/]

British Columbia Ministry of Forests (BC MOF). 2014. Biogeoclimatic Ecosystem Classification Program.

[http://www.for.gov.bc.ca/hre/becweb/]

British Columbia Ministry of Forests (BC MOF) and British Columbia Ministry of Environment, Lands and Parks (MELP). 1999. Landscape Unit Planning Guide. British Columbia Ministry of Forests and Ministry of Environment, Lands and Parks, Victoria, BC.

Broders, H.G., G.J. Forbes, S. Woodley, and I.D. Thompson. 2006. Range extent and stand selection for roosting and foraging in forest-dwelling Northern Long-eared Bats and Little Brown Bats in the Greater Fundy Ecosystem, New Brunswick. Journal of Wildlife Management 70(5):1174-1184.

Bryant, A.A. 1987. A reconnaissance of potential bat hibernacula in the southern Okanagan Valley, British Columbia. Prepared for the World Wildlife Fund (Canada), B.C. Ministry of Environment, Lands and Parks, Victoria, BC, and the Federation of BC Naturalists. 17pp.

Buchalski, M.R., J.B. Fontaine, P.A. Heady, J.P. Hayes, and W.F. Frick. 2013. Bat response to differing fire severity in mixed-conifer forest California, USA. [PLoS ONE 8 (3):e57884. DOI: 10.1371/journal.pone.0057884]

Bunnell, F.L., L.L. Kremsater, and E. Wind. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands. Environmental Review 7(3):97-146.

Burford, L.S., M.J. Lacki, and C.V. Covell, Jr. 1999. Occurrence of moths among habitats in a mixed mesophytic forest: implications for management of forest bats. Forest Science 45(3):323–329.

Burles, D.W. 2000. Bats of Gandl K'in. Pp. 322–326 *in* L.M. Darling, ed. Proceedings of a conference on the biology and management of species and habitats at risk, Kamloops, B.C., 15–19 February 1999. Vol. 1. B.C. Ministry of Environment, Lands and Parks, Victoria, BC and University College of the Cariboo, Kamloops, BC 490pp.

Burles, D.W. 2001. Influence of weather on the life history of two bats, *Myotis lucifugus* and *Myotis keenii* at Gandle K'in, Haida Gwaii. M.Sc. Thesis, University of Victoria, Victoria, BC. 150pp.

Burles, D. W., R. M. Brigham, R. A. Ring and T. E. Reimchen. 2008. Diet of two insectivorous bats, *Myotis lucifugus* and *Myotis keenii*, in relation to arthropod abundance in a temperate Pacific Northwest rainforest environment. Canadian Journal of Zoology 86: 1367-1375.

Caceres, C. 1998*a*.The foraging and roosting ecology of the Myotis bats of the interior wet-belt, British Columbia. Prepared for the Columbia Basin Fish and Wildlife Program, Nelson, BC.

Caceres, M.C. 1998*b*. The summer ecology of *Myotis* species bats in the interior wet-belt of British Columbia. M.Sc. Thesis, University of Calgary, Calgary, AB. 102pp.

Caceres, M.C., and M.J. Pybus. 1997. Status of the Northern Long-eared Bat (*Myotis septentrionalis*) in Alberta. Alberta Environmental Protection, Wildlife Management Division, Edmonton, AB. Wildlife Status Report No. 3. 19pp.

Caire, W.R.K., R.V. LaVal, M.L. LaVal, and R. Clawson. 1979. Notes on the ecology of *Myotis keenii* (Chiroptera, Vespertilionidae) in eastern Missouri. American Midland Naturalist 102:404–407.

Canadian Council of Forest Ministers (CCFM). 2003. National Forestry Database Program.[http://nfdp.ccfm.org/index.htm]

Chapman, K., K. McGuinness, and R.M. Brigham. 1994. Status of the Pallid Bat in British Columbia. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC. Wildlife Working Report No. WR-61. 26pp.

Chatwin, T.A. 2004. Keen's Long-eared Myotis, *Myotis keenii*. Accounts and measures for managing Identified Wildlife – Accounts V. 2004. B.C. Ministry of Water, Land and Air Protection, Victoria, BC. 7pp. [http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Mammals/m_keensmyotis.pdf]

Chen, J., S.C. Saunders, T.R. Crow., R.J. Naiman, K.D. Brosofske, G.D. Mroz, B.L. Brookshire, and J.F. Franklin. 1999. Microclimate in forest ecosystem and landscape ecology. BioScience 49:288–297.

Christy, R.E., and S.D. West. 1993. Biology of bats in Douglas-fir forests. In: M. H. Huff, R. M. Holthausen, and K. B. Aubry. Technical editors. "Biology and management of old-growth forests." U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. General Technical Report PNW-GTR-308. 28pp.

Chruszcz, B. 1999. Foraging and thermoregulatory behaviour of the Long-eared Bat (*Myotis evotis*) roosting in natural habitat. M.Sc. Thesis, University of Calgary, Calgary, AB.

Chruszcz, B.J., and R.M.R. Barclay. 2002. Thermoregulatory ecology of a solitary bat, *Myotis evotis*, roosting in rock crevices. Functional Ecology 16:8-26.

Chung-MacCoubrey, A.L. 1996. Grassland bats and land management in the southwest. Pp. 60–63 *in* D.M. Finch, ed. 1996. Ecosystem disturbance and wildlife conservation in western grasslands - a symposium proceedings. September 22–26, 1994, Albuquerque, NM. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, General Technical Report RM-GTR-285. 82pp.

Ciechanowski, M. 2002. Community structure and activity of bats (Chiroptera) over different water bodies. Mammalian Biology 67(5):276–285.

Clare, E.L., B.R. Barber, B.W. Sweeney, P.D.N. Hebert, and M.B. Fenton. 2011. Eating local: influences of habitat on the diet of Little Brown Bats (*Myotis lucifugus*). Molecular Ecology 20:1772–1780.

Clark, D.R., Jr., T.H. Kunz, and T.E. Kaiser. 1978. Insecticides applied to a nursery colony of Little Brown Bats (*Myotis lucifugus*): lethal concentrations in brain tissue. Journal of Mammalogy 59:84–91.

Clark, B.C., D.M Leslie, Jr., and T.S. Carter. 1993. Foraging activity of adult female Ozark Big-eared Bats (*Plecotus townsendii ingens*) in summer. Journal of Mammalogy 74:422–427.

Coleman, J.L., and R.M.R. Barclay. 2011. Influence of urbanization on demography of Little Brown Bats (*Myotis lucifugus*) in the prairies of North America. PLoS ONE 6(5):e20483 1–10.

Collard, T.S., S.D. Grindal, R.M. Brigham, and R.M.R. Barclay. 1990. Identification of the status and critical habitats of the Spotted Bat (*Euderma maculatum*), Pallid Bat (*Antrozous pallidus*), and Fringed Bat (*Myotis thysanodes*) in the south Okanagan Valley, British Columbia. Submitted to the World Wildlife Fund, B.C. Ministry of Environment, and B.C. Habitat Conservation Fund. 28pp.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2004. COSEWIC assessment and update status report on the Fringed Bat *Myotis thysanodes* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. vii + 26pp. [http://publications.gc.ca/collections/Collection/CW69-14-396-2004E.pdf]

Cornelison, C.T., K.T., Gabriel, C., Barlament, S.A., Crow, Jr. 2014. Inhibition of *Pseudogymnoascus destructans* growth from conidia and mycelial extension by bacterially produced volatile organic compounds. Mycopathologia. 177: 1–10.

Craig, V.J. 2003. British Columbia status report on Townsend's Big-eared Bat, *Corynorhinus townsendii*. Draft report. Prepared for the B.C. Ministry of Water, Land and Air Protection, Victoria, BC. 45pp.

Craig, V.J., and S.L. Holroyd. 2004. Bat conservation strategy for B.C. and Alberta. Draft. Prepared for the B.C. Ministry of Water, Land and Air Protection, Victoria, BC. 112pp.

Crampton, L., and R.M.R. Barclay. 1996. Habitat selection by bats in fragmented and unfragmented aspen mixedwood stands of different ages. Pp. 238–359 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Crampton, L.H., and R.M. Barclay. 1998. Selection of roosting and foraging habitat by bats in different-aged mixedwood stands. Conservation Biology 12:1347-1358.

Cross, S.P. 1988. Riparian systems and small mammals and bats. Pp. 93–112 *in* K. J. Raedeke, ed. Streamside management: riparian wildlife and forestry interactions. University of Washington, Seattle, WA. Institute of Forest Resources Contribution 59.

Davis, M., A. Vandenburg, T. Chatwin, and M. Mather. 1999. Bat usage of the Weymer Creek cave systems on northern Vancouver Island. Prepared for the B.C. Ministry of Environment, Lands and Parks, Nanaimo, BC. Presented at the Species and Habitats at Risk Conference, February, 1999, Kamloops, BC. [http://www.env.gov.bc.ca/wld/documents/ce14davis.pdf]

DeJong, J. 1994. Distribution patterns and habitat use by bats in relation to landscape heterogeneity, and consequences for conservation. Ph.D. Thesis, University of Agricultural Sciences, Uppsala, Sweden.

Doucett, R.R., H.G. Broders, G. Quinn, and G.J. Forbes. 2002. Those vain aerial ways: determining the relative importance of aquatic and terrestrial insects in the diets of bats. Presentation to the 3rd International Conference on Applications of Stable Isotope Techniques, April 29–May 1, 2002, Flagstaff, AZ.

Driscoll, C.T., Y-J Han, C.Y. Chen, D.C. Evers, K. Fallon Lambert, T.M. Holsen, N.C. Kamman, and R.K. Munson. 2007. Mercury contamination in forest and freshwater ecosystems in the northeastern United States. BioScience 57:17–28.

Dunster, J., and K. Dunster 1996. Natural resource management dictionary. University of British Columbia, Vancouver, BC. 380pp.

Easterla, D.A., and J.O. Whitaker, Jr. 1972. Food habits of some bats from Big Bend National Park, Texas. Journal of Mammalogy 53:887–890.

Ekman, M., and J. de Jong. 1996. Local patterns of distribution and resource utilization of four bat species (*Myotis brandti, Eptesicus nilssoni, Plecotus* *auritus, and Pipistrellus pipistrellus*) in patchy and continuous environments. Journal of Zoology (London) 238:571–580.

Entwistle, A.C., S. Harris, A.M. Hutson, P.A. Racey, A. Walsh, S.D. Gibson, I. Hepburn, and J. Johnston. 2001. Habitat management for bats: a guide for land managers, land-owners and their advisors. Joint Nature Conservation Committee, Peterborough, UK. 48pp.

Environmental Assessment Office. 2013*a*. Guideline for the selection of valued components and assessment of potential effects. Available here

Environmental Assessment Office. 2013*b*. Project information centre. Available here.

Erickson, J.L., and S.D. West. 1996. Managed forests in the western Cascades: the effects of seral stage on bat habitat use patterns. Pp. 215–227 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Estrada, A., and R. Coates-Estrada. 2001. Bat species richness in live fences and in corridors of residual rain forest vegetation at Los Tuxtlas, Mexico. Ecography 24:94–102.

Evelyn, M.J., D.A. Stiles, and R.A. Young. 2004. Conservation of bats in suburban landscapes: roost selection by *Myotis yumanensis* in a residential area in California. Biological Conservation 115:463–473.

Faure, P.A., and R.M.R. Barclay. 1994. Substrate-gleaning versus aerial-hawking: plasticity in the foraging and echolocation behavior of the Long-eared Bat, *Myotis evotis*. Journal of Comparative Physiology A 174:651–660.

Faure, P.A., J.H. Fullard, and J.W. Dawson. 1993. The gleaning attacks of the northern long-eared bat, *Myotis septentrionalis*, are relatively inaudible to moths. Journal of Experimental Biology 178:173–189.

Fenton, M.B. 1969. Summer activity of *Myotis lucifugus* (Chiroptera: Vespertilionidae) at hibernacula in Ontario and Quebec. Canadian Journal of Zoology 47:597–602.

Fenton, M.B. 1983. Just bats. University of Toronto Press, Toronto, ON. 165pp.

Fenton, M.B. 1990. The foraging behaviour and ecology of animal-eating bats. Canadian Journal of Zoology 68(3):411–422.

Fenton, M.B. 1997. Science and the conservation of bats. Journal of Mammalogy 1–14.

Fenton, M.B., and R.M. Barclay. 1980. *Myotis lucifugus*. Mammalian Species 142:1–8.

Fenton, M.B., R.M.R. Barclay, R.M. Brigham, D. Burles, and D. Volkers. 2002. September day-roosts of *Myotis keenii* and *Myotis lucifugus* in Gwaii Haanas Park Reserve/ Haida Heritage Site, British Columbia. Report submitted to Endangered Species Recovery Fund. 15pp.

Fenton, M.B., C.G. van Zyll de Jong, G.P. Bell, D.B. Campbell, and M. LaPlante. 1980. Distribution, parturition dates and feeding of bats in south-central British Columbia. Canadian Field-Naturalist 94(4):416–420.

Findley, J.S. 1993. Bats: a community perspective. Cambridge University Press, Cambridge, UK. 167pp.

Firman, M.C. 1997. Conservation of the Saint Eugene Mission Townsend's Big-eared Bat (*Plecotus townsendii*) colony. Prepared for the Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC.

Firman, M.C. 1999. Townsend's Big-eared Bat (*Plecotus townsendii)* in the East Kootenay. Prepared for the Columbia Basin Fish and Wildlife Compensation Program, Invermere BC.

Firman, M. 2003. Update: Townsend's Big-eared Bat (*Plecotus townsendii*) in the East Kootenays. Prepared for the Columbia Basin Fish and Wildlife Compensation Program. 35pp.

Firman, M.C., C. Godwin, and R.M.R. Barclay. 1995. Bat fauna survey of the west Shuswap and South Thompson River region, B.C. Prepared for the B.C. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC.

Fitch, J.H., and K.A. Shump, Jr. 1979. *Myotis keenii*. Mammalian Species 121:1–3.

Fleming, T.H., and P. Eby. 2003. Ecology of bat migration. Pp. 156–208 *in* T.H. Kunz and M.B. Fenton, eds. Bat ecology. University of Chicago Press, Chicago, IL. 779pp.

Forest Practices Code of British Columbia. 1995. Riparian management area guidebook. B.C. Ministry of Forests, Victoria, BC. [http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/rip-toc.htm]

French, S.P., M.G. French, and R.R. Knight. 1994. Grizzly bear use of army cutworm moths in the Yellowstone ecosystem. International Conference on Bear Research and Management 9(1):389–399. [http://www.bearbiology.com/fileadmin/tpl/Downloads/URSUS/Vol_9/French_French_Vol_9.pdf]

Fukui, D., M. Murakami, S. Nakano and T. Aoi. 2006. Effect of emergent aquatic insects on bat foraging in a riparian forest. Journal of Animal Ecology 75:1252-1258.

Fullard, J.H., M.B. Fenton, and C.L. Furlonger. 1983. Sensory relationships of moths and bats sampled from two Nearctic sites. Canadian Journal of Zoology 61:1752–1757.

Furlonger, C.L., H.J. Dewar, and M.B. Fenton. 1987. Habitat use by foraging insectivorous bats. Canadian Journal of Zoology 65:284–288.

Garcia, P.F.J., S.A. Rasheed, and S.L. Holroyd. 1995. Status of the Western Small-footed Myotis in British Columbia. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC. Wildlife Working Report No. WR-74. 14pp.

Gargas, A., M.T. Trest, M. Christensen, T.J. Volk, and D.S. Blehert. 2009. *Geomyces destructans* sp. nov. associated with bat white-nose syndrome. Mycotaxon 108:147–154. [http://botit.botany.wisc.edu/toms_fungi/147gargas9-73.pdf]

Glover, A.M., and J.D. Altringham. 2008. Cave selection and use by swarming bat species. Biological Conservation 141:1493–1504.

Grindal, S.D. 1995. Habitat use by bats in fragmented forest. Bat Research News 36:26.

Grindal, S.D. 1996. Habitat use by bats in fragmented forests. Pp. 260–272 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Grindal, S.D. 1998. Habitat use by bats in second- and old-growth stands in the Nimpkish Valley, Vancouver Island. Pp. 116–118 *in* J.A. Trofymow and A. Mackinnon, eds. Proceedings of a workshop on structure, process, and diversity in successional forests of coastal British Columbia. February 17–19, 1998, Victoria, BC. Northwest Science 72 (special issue No. 2).

Grindal, S.D., and R.M. Brigham. 1998. Short-term effects of small-scale habitat disturbance on activity by insectivorous bats. Journal of Wildlife Management 62:996–1003.

Grindal, S.D, T.S. Collard, and R.M. Brigham. 1991. Evidence for a resident breeding population of Pallid Bats, (*Antrozous pallidus*) in British Columbia. Royal British Columbia Provincial Museum, Contributions to Natural Science 14:1–4.

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

Grindal, S.D, J.L. Morissette, and R.M. Brigham. 1999. Concentration of bat activity in riparian habitats over an elevational gradient. Canadian Journal of Zoology 77:972–979.

Grinevitch, L., S.L. Holroyd, and R.M.R. Barclay. 1995. Sex differences in the use of daily torpor and foraging time by Big Brown Bats (*Eptesicus fuscus*) during the reproductive season. Journal of Zoology (London) 235:301–309.

Hamilton, I.M., and R.M. R. Barclay. 1994. Patterns of daily torpor and day-roost selection by male and female Big Brown Bats (*Eptesicus fuscus*). Canadian Journal of Zoology 72:744–749.

Hayes, J.P., and M.D. Adam. 1996. The influence of logging riparian areas on habitat utilization by bats in western Oregon. Pp. 228–237 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Heinrich, R., M. Todd, B. Beck, R. Bonar, J. Beck, and R. Quinlan. 1999. Hoary Bat summer roosting habitat. Habitat suitability index model, Version 5.Foothills Model Forest Publications, Hinton, AB. 5pp.

Henderson, L.E., and H.G. Broders. 2008. Movements and resource selection of the Northern Long-eared Myotis (*Myotis septentrionalis*) in a forest-agriculture landscape. Journal of Mammalogy 89:952–963. [http://www.smu.ca/faculty/hughbroders/documents/jmamm08pei.pdf]

Herd, R.M., and M.B. Fenton. 1983. An electrophoretic, morphological and ecological investigation of a putative hybrid zone between *Myotis lucifugus* and *Myotis yumanensis* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 61:2029–2050.

Hickey, M.B., and M.B. Fenton. 1990. Foraging by Red Bats (*Lasiurus borealis*): Do intraspecific chases mean territoriality? Canadian Journal of Zoology 68:2477–2482.

Hill, T., R. Clarke, and P. Stent. 2007. 2007 West Kootenay Fringed Myotis Project. Fish and Wildlife Compensation Project – Columbia Basin, Nelson, BC. 9pp. [http://www.env.gov.bc.ca/wildlife/wsi/reports/4695_WSI_4695_RPT_2007.PDF]

Hill, T., A. Reid, R. Clarke, and J. Gwilliam. 2005. West Kootenay Townsend's Big-eared Bat Progress Report. Prepared for the Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC and FortisBC. 27pp.

Hill, T., A. Reid, R. Clarke, and J. Gwilliam. 2006a. West Kootenay Townsend's Big-eared Bat Progress Report. Prepared for the Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC. and FortisBC. Draft.

Hill, T., A. Reid, R. Clarke, J. Krebs, and J. Gwilliam. 2006b. West Kootenay Townsend's Big-eared Bat (*Corynorhinus townsendii*) Project–Final Report. Fish and Wildlife Compensation Program – Columbia Basin, Nelson, BC. 70pp. [http://www.env.gov.bc.ca/wildlife/wsi/reports/4659_WSI_4659_RPT_2006.PDF]

Hitchcock, H. B. 1965. Twenty-three years of bat banding in Ontario and Quebec. Canadian Field Naturalist 79:4–14.

Holloway, G.L. 1998. The ecology of prairie-dwelling bats in southeastern Alberta. M.Sc. Thesis, University of Calgary, Calgary, AB.

Holloway, G.L., and R.M.R. Barclay. 2000. Importance of prairie riparian zones to bats in southeastern Alberta. Ecoscience 7:115–122.

Holloway, G.L., and R.M.R. Barclay. 2001. *Myotis ciliolabrum*. Mammalian Species 670(1):1–5.

Holroyd, S. 1993. Influences of some extrinsic and intrinsic factors on reproduction by Big Brown Bats (*Eptesicus fuscus*) in southeastern Alberta. M.Sc. Thesis, University of Calgary, Calgary, AB. 126pp.

Holroyd, S.L., R.M.R. Barclay, L.M. Merk, and R.M. Brigham. 1994. A survey of the bat fauna of the dry interior of British Columbia. Prepared for the B.C. Ministry of Environment, Lands and Parks, Victoria, BC. Wildlife Working Report No. WR-63. 73pp.

Holroyd, S.L., and V.J. Craig. 2001. Townsend's Big-eared Bat inventory of Quadra, Cortes, Denman and Hornby Islands: progress report. Unpublished report for the Habitat Conservation Trust Fund.

Humphrey, S.R. 1975. Nursery roosts and community diversity of Nearctic bats. Journal of Mammalogy 56:321–346.

Humphrey, S.R., and T.H. Kunz. 1976. Ecology of a Pleistocene relict, the Western Big-eared Bat (*Plecotus townsendii*) in the southern Great Plains. Journal of Mammalogy 57:470–494.

Hutchinson, J.T., and M.J. Lacki. 2000. Selection of day roosts by Red Bats in mixed mesophytic forests. Journal of Wildlife Management 64:87–94.

Ihlo, C.M. 2013. Predicting the spread of white-nose syndrome in bats: a strategy for prioritizing resources. Duke University, M.E.M. Nicholas School of the Environment, Durham, NC. 38pp.

Ilhardt, B.L., E.S. Verry, and B.J. Palik. 2000. Defining the riparian zone. Pp. 7–15 *in* R.G. Wagner and J.M. Hagan, eds. Conference proceedings. Forestry and the riparian zone. October 26, 2000, University of Maine, Orono, ME. 88pp.

Jamieson, B., E. Peterson, M. Peterson, and I. Parfitt. 2001. The conservation of hardwoods and associated wildlife in the CBFWCP area in southeastern British Columbia. Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC. 98pp.

Johnson, J.S., M.J. Lacki, and M.D. Baker. 2007. Foraging ecology of Long-legged Myotis (*Myotis volans*) in north-central Idaho. Journal of Mammalogy 88:1261–1270.

Jones, P.F., B.A. Downey, B.N. Taylor, J.P. Landry, R.W. Quinlan, K.J. Kissner, C.L. Skiftun, and D.L. Gummer. 2003. A multi-species conservation strategy for species at risk in the Milk River basin: habitat suitability models for selected wildlife management species. Interim Report. Alberta Sustainable Resource Development, Department of Fish and Wildlife, and the Alberta Conservation Association. 118pp.

Jones, G., D.S. Jacobs, T.H. Kunz, M.R. Willig, and P.A. Racey. 2009. Carpe noctem: the importance of bats as bioindicators. Endangered Species Research 8(1–2):93–115.

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

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

Kalcounis, M.C., and K.R. Hecker. 1996. Intraspecific variation in the tree-roost site selection by Little Brown Bats (*Myotis lucifugus*). Pp. 81–90 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Keeley, B.W. and M. D. Tuttle. 1999. Bats in American Bridges. Bat Conservation International, Inc. Resource Publication No. 4. 41pp.

Kellner, A.M. 1999. Activity and roost selection of bats in montane forests on northern Vancouver Island. M.Sc. Thesis, Simon Fraser University, Burnaby, BC.

Kellner, M., and S. Rasheed. 2001. BC Hydro Bridge-Coastal Restoration Program Campbell River Watershed bat habitat enhancement and inventory project. Year 1 progress report. Prepared for BC Hydro, Bridge-Coastal Fish and Wildlife Restoration Program, Burnaby, BC.

Kellner, M., and S. Rasheed. 2002. Campbell River Bat Project: inventory and habitat enhancement. Prepared for BC Hydro Bridge-Coastal Fish and Wildlife Restoration Program, Burnaby, BC. 63pp.

Keinath, D.A. 2003. Species assessment for fringed myotis (*Myotis thysanodes*) in Wyoming. Prepared for the U.S. Department of the Interior, Bureau of Land Management, Wyoming State Office, Cheyenne, Wyoming. 71 pp.

Kerth, G., N. Perony, and F. Schweitzer. 2011. Bats are able to maintain long-term social relationships despite the high fission-fusion dynamics of their groups. Proceedings of the Royal Society B: Biological Sciences, 278(1719): 2761-2767.

Kiser, M., and S. Kiser. 1999. Bat houses and exclusion in British Columbia. Bat Research News 7:3–4.

Kiser, M., and S. Kiser. 2004. The bat house researcher 12(1). [http://batcon.org/pdfs/bathouses/ResearchFinal.pdf]

Knight, T., and G. Jones. 2009. Importance of night roosts for bat conservation: roosting behaviour of the lesser horseshoe bat *Rhinolophus hipposideros*. Endangered Species Research, 8: 79-86. [http://www.int-res.com/articles/esr2009/8/n008p079.pdf]

Kocher, S.D., and E.H. Williams. 2000. The diversity and abundance of North American butterflies vary with habitat disturbance and geography. Journal of Biogeography 27:785–794.

Koehler, C.E. 1991. The reproductive ecology of the Hoary Bat (*Lasiurus cinereus*) and its relation to litter size variation in vespertilionid bats. M.Sc. Thesis, University of Calgary, Calgary, AB. 99pp.

Kremsater, L., and F.L. Bunnell. 1999. Edge effects: theory, evidence and implications to management of western North American forests. Pp. 117–153 *in* J.M. Rochelle, L.A. Lehmann, and J. Wisniewski, eds. Forest fragmentation: wildlife and management implications. Brill, Leiden, Netherlands.

Krusic, R.A., and C.D. Neefus. 1996. Habitat associations of bat species in the White Mountain National Forest. Pp. 185–198 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Krusic, R.A., M. Yamasaki, C.D. Neefus,, and P.J. Pekins. 1996. Bat habitat use in White Mountain National Forest. Journal of Wildlife Management 60:625–631.

Kunz, T.H. 1982*a*. *Lasionycteris noctivagans*. Mammalian Species 172:1–5.

Kunz, T.H. 1982*b*. Roosting ecology of bats. Pp. 1–55 i*n* T.H. Kunz, ed. Ecology of bats. Plenum Press, New York. 425pp.

Kunz, T.H. 2009. Joint oversight hearing on white-nose syndrome: What's killing bats in the northeast? U.S. Committee on Natural Resources, June 2009. Presentation to the Committee. [http://naturalresources.house.gov/calendar/eventsingle.aspx?EventID=166135 – accessed December 2014].

Kunz, T.H., E.L.P. Anthony, and W.T. Rumage. 1977. Mortality of Little Brown Bats following multiple pesticide applications. Journal of Wildlife Management 41:476–483.

Kunz, T.H., and M.B. Fenton, eds. 2006. Bat ecology. University of Chicago Press, Chicago, IL. 779pp.

Kunz, T.H., and R.A. Martin. 1982. *Plecotus townsendii*. Mammalian Species 175:1–6.

Kunz, T.H., and J.D. Reichard. 2010. Status review of the Little Brown Myotis (*Myotis lucifugus*) and determination that immediate listing under the *Endangered Species Act* is scientifically and legally warranted. Status Review prepared for U.S. Fish and Wildlife Service. [http://www.bu.edu/cecb/files/2010/12/Final-Status-Review.pdf]

Kurta, A., G.P. Bell, K.A. Nagy, and T.H. Kunz. 1989. Energetics of pregnancy and lactation in free-ranging Little Brown Bats (*Myotis lucifugus*). Physiological Zoology 62:804–818.[http://www.bu.edu/cecb/files/2009/08/physzool623804-181989.pdf]

Kurta, A., and R.H. Baker. 1990. *Eptesicus fuscus*. Mammalian Species 356:1–10.

Kurta, A., K.A. Johnson, and T.H. Kunz. 1987. Oxygen consumption and body temperature of female Little Brown Bats (*Myotis lucifugus*) under simulated roost conditions. Physiological Zoology 60:386–397.

Kurta, A., and J.A. Teramino. 1992. Bat community structure in an urban park. Ecography 15:257–261.

Lacki, M.J., S.K. Amelon, and M.D. Baker. 2007. Foraging ecology of bats in forests. Pp. 83–127 *in* M.J. Lacki, J.P. Hayes, and A. Kurta, eds. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, MD.

Lacki, M.J., and J.H. Schwierjohann. 2001. Day-roost characteristics of northern bats in mixed mesophytic forest. Journal of Wildlife Management 65:482–488.

Laidlaw, G.W.J., and M.B. Fenton. 1971. Control of nursery colony populations of bats by artificial light. Journal of Wildlife Management 35(4):843–846.

Lausen, C.L. 2001. Thermoregulation and roost selection by reproductive Big Brown Bats (*Eptesicus fuscus*) roosting in the South Saskatchewan River Valley, Alberta. M.Sc. Thesis, University of Calgary, Calgary, AB. 119pp.

Lausen, C.L. 2003. Roosting ecology of the Western Small-footed Bat (*Myotis ciliolabrum*) in southeastern Alberta. Mountain Equipment CO-OP. Final research report. 20pp.

Lausen, C. 2013. Identifying and securing hibernation habitat for bats in the Columbia Basin in response to risk of White Nose Syndrome. Year 2 end of season report. Available: http://static1.squarespace.com/static/529bc87be4b0d8d4512dadc4/t/52d6d253e4b065c7c0eae686/1389810259844/2013+FWCP+Yr2+Bat+Report.pdf

Lausen, C.L. 2015. Seeking silver in southeast British Columbia mines: Hibernation ecology of silver-haired bats. Joint North American Bat Working Groups meeting, St. Louis, MO. 3 – 6 March 2015.

Lausen, C.L., and R.M.R. Barclay. 2002. Roosting behaviour and roost selection of female Big Brown Bats (*Eptesicus fuscus*) roosting in rock crevices in southeastern Alberta. Canadian Journal of Zoology 80:1069-1076.

Lausen, C.L., and R.M.R. Barclay. 2003. Thermoregulation and roost selection by reproductive female Big Brown Bats (*Eptesicus fuscus*) roosting in rock crevices. Journal of Zoology (London) 260:235-244.

Lausen, C.L., and R.M.R. Barclay. 2006. Winter bat activity in the Canadian Prairies. Canadian Journal of Zoology 84:1079-1086.

Lausen, C., and T. Hill. 2010. A summary of bat work in 2009 in the Columbia Basin as part of the provincial taxonomic study of Long-eared Bats in B.C. Prepared for Fish and Wildlife Compensation Program – Columbia Basin, Nelson, BC. 37pp.

Lausen, C L and T J Hill. 2016. Hibernation ecology of silver-haired bats overwintering in British Columbia Canada. Society for Northwest Vertebrate Biology Annual Meeting, 23-24 Feb 2016, Coeur d'Alene Idaho. Available here.

Lausen, C.L., and Isaac, L.A. 2015. Determining species diversity and population size of bats at the ReMac mine, Pend D'Oreille Valley, BC. Joint North American Bat Working Groups meeting, St. Louis, MO. 3 – 6 March 2015. poster

Leonard, M., and M.B. Fenton. 1983. Habitat use by Spotted Bats (*Euderma maculatum*, Chiroptera: Vespertilionidae): roosting and foraging behaviour. Canadian Journal of Zoology 61:1487–1491.

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

Limpens, H.J.G.A., and K. Kapteyn. 1991. Bats, their behavior and linear landscape elements. Myotis 29:39-48.

Lorch, J.M., C.U. Meteyer, M.J. Behr, J.G. Boyles, P.M. Cryan, A.C. Hicks, A.E. Ballman, J.E. Coleman, D.N. Redell, D.M. Reeder, and D.S. Blehert. 2011. Experimental infection of bats with *Geomyces destructans* causes white-nose syndrome. Nature 480:376-378.

Lunde, R.E., and A.S. Harestad. 1986. Activity of Little Brown Bats in coastal forests. Northwest Science 60:206-209.

Macdonald, J.S., E.A. MacIsaac, and H.E. Herunter. 2003. The effect of variable-retention riparian buffer zones on water temperatures in small headwater streams in sub-boreal forest ecosystems of British Columbia. Canadian Journal of Forest Research 33:1371-1382.

Mackey, R.L., and R.M.R. Barclay. 1989. The influence of physical clutter and noise on the activity of bats over water. Canadian Journal of Zoology 67:1167-1170.

Manning, R.W., and J.K. Jones, Jr. 1989. *Myotis evotis*. Mammalian Species 329:1-5.

Maser, C., R.G. Anderson, K. Cromack Jr., J.T. Williams and R.E. Martin. 1979. Dead and down woody material. Pp. 78-95 *in* J.W. Thomas tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Forest Service Agricultural Handbook No. 553.

McGuire, L.P., C.G. Guglielmo, S.A. MacKenzie, P.D. Taylor. 2012. Migratory stopover in the long-distance migrant silver-haired bat, *Lasionycteris noctivagans*. Journal of Animal Ecology 81:377-385.

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

Miller, J.C. 2000. Monitoring the effects of *Bacillus thuringiensis kurstaki* on nontarget Lepidoptera in woodlands and forests of Western Oregon. Pp. 277–286 in P.A. Follet and J.J. Duan, eds. Nontarget effects of biological control. Kluwer Academic Publishers, Boston, MA.

Milligan, B.N., and R.M. Brigham. 1993. Sex ratio variation in the Yuma Bat (*Myotis yumanensis*). Canadian Journal of Zoology 71:937-940.

Milne, L., and M. Milne. 1988. The Audubon Society field guide to North American insects and spiders. Alfred A. Knopf, New York, Chanticleer Press Edition. 989pp.

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

Nagorsen, D.W. 2009. Campbell River Project: bat house mitigations. Prepared for BC Hydro Bridge Coastal Fish and Wildlife Restoration

Program Burnaby, BC. Bridge Coastal Fish and Wildlife Restoration Project #06.W.CBR.03. 24pp. [http://www.bchydro.com/bcrp/projects/docs/bridge_river/06.W.CBR.03.pdf]

Nagorsen, D.W., and R.M. Brigham. 1993. Bats of British Columbia. Royal British Columbia Museum Handbook.Vol.1. The Mammals of British Columbia. UBC Press, Vancouver, BC. 164pp.

Nagorsen, D.W. and B. Paterson. 2012. An update on the status of Red Bats, *Lasiurus blossevillii* and *Lasiurus borealis*, in British Columbia. Northwestern Naturalist 93:235-237.

New Brunswick Department of Natural Resources (DNR). 2011. White-nose Syndrome. Fact Sheet. CNB 9497. 3pp. [http://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Wildlife/Bats-WhiteNoseSyndrome.pdf – accessed December 2014].

Norberg, U.M., and J.M. Rayner. 1987. Ecological morphology and flight in bats (Mammalia; Chiroptera): wing adaptations, flight performance, foraging strategy and echolocation. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 316:335–427.

Nova Scotia Department of Natural Resources (DNR). 2011. Early Signs of White-nose Syndrome Spreading to Bats. News Release. [http://novascotia.ca/news/release/?id=20110418001 – accessed December 2014].

Ober, H.K., and J.P. Hayes. 2008. Prey selection by bats in forests of western Oregon. Journal of Mammalogy 89:1191–1200.

O'Farrell, M.J., and E.H. Studier. 1980. *Myotis thysanodes*. Mammalian Species 137:1–5.

Ontario Ministry of Natural Resources (MNR). 2013. Wildlife Management. Bats and White-nose syndrome. [http://www.mnr.gov.on.ca/en/Business/FW/2ColumnSubPage/278166.html accessed March 2014].

Ormsbee, P.C. 1996. Characteristics, use, and distribution of day roosts selected by female *Myotis volans* (Long-legged Myotis) in forested habitat of the central Oregon Cascades. Pp. 124–131 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Ormsbee, P.C., and W.C. McComb. 1998. Selection of day roosts by female Long-legged Myotis in the central Oregon Cascade Range. Journal of Wildlife Management 62:596-603.

O'Shea, T.J., L.E. Ellison, and T.R. Stanley. 2011. Adult survival and population growth rate in Colorado big brown bats (*Eptesicus fuscus*). Journal of Mammalogy 92: 433-443.

Owen, S.F., and M.A. Menzel. 2003. Home-range size and habitat used by the Northern Myotis (*Myotis septentrionalis*). American Midland Naturalist 150:3352–359.

Panzer, R., and M.W. Schwartz. 1998. Effectiveness of a vegetation-based approach to insect conservation. Conservation Biology 12 (3):693–702.

Parker, D.I., and J.A. Cook. 1996. Keen's Long-eared Bat, *Myotis keenii*, confirmed in southeast Alaska. Canadian Field-Naturalist 110:611–614.

Parker, D.I., J.A. Cook, and S.W. Lewis. 1996. Effects of timber harvest on bat activity in southeastern Alaska's temperate rainforests. Pp. 277–292 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Parsons, S., K.J, Lewis, and J.M. Psyllakis. 2003. Relationships between roosting habitat of bats and decay of aspen in the sub-boreal forests of British Columbia. Forest Ecology and Management 177:559–570.

Perkins, M. 1998. *Eptesicus fuscus*, Big Brown Bat. Species Account. Western Bat Working Group.[http://www.wbwg.org/]

Perkins, J.M., and S.P. Cross. 1988. Differential use of some coniferous forest habitats by hoary and Silver-haired Bats in Oregon. Murrelet 69:21–24.

Perlmeter, S. 1996. Bats and bridges: patterns of night roost activity in the Willamette National Forest. Pp. 132–151 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Podlutsky, A.J., A.M. Khritankov, N.D. Ovodov, and S.N. Austad. 2005. A new field record for bat longevity. Journals of Gerontology Series A: Biological Sciences and Medical Sciences 60(11):1366–1368.

Prince Edward Island Department of Agriculture and Forestry (DAF). 2013. Bat white-nose syndrome confirmed. [http://www.whitenosesyndrome.org/sites/default/files/files/bat_white_nose_confirmed_feb_27.final_provincial_press_release.pdf – accessed December 2014].

Puechmaille, S., P. Verdeyroux, H. Fuller, M. ArGouilh, M. Bekaert, and E. Teeling. 2010. White-nose syndrome fungus (*Geomyces destructans*) in bat, France. Emerging Infectious Diseases 16:290–293.

Quayle, J. 2003. Glossary of monitoring terms. Unpublished.

Quebec Ministère des Ressources naturelles et de la Faune (MNRF). 2010. White-nose syndrome in bat populations. The presence of the syndrome is confirmed in Quebec. Press Release. 2 pp. [http://www.batcon.org/pdfs/whitenose/QuebecWNSPressRelease.pdf – accessed December 2014].

Rabe, M.J., T.E. Morrell, H. Green, J.C. deVos, Jr., and C.R. Miller. 1998. Characteristics of ponderosa pine snag roosts used by reproductive bats in northern Arizona. Journal of Wildlife Management 62:612–621.

Racey, P.A., and A.C. Entwistle. 2003. Conservation ecology of bats. Pp. 680–743 *in* T.H. Kunz and M.B. Fenton, eds. Bat ecology. University of Chicago Press, Chicago, IL. 779pp.

Racey, P.A., and S.M. Swift. 1981. Variations in gestation length in a colony of pipistrelle bats (*Pipistrellus pipistrellus*) from year to year. Journal of Reproductive Fertility 61:123–129.

Rainey, W.E. 1998. *Myotis lucifugus*, Little Brown Bat. Species Account. Western Bat Working Group.[http://www.wbwg.org/]

Rainho, A., and J.M. Palmeirin. 2011. The importance of distance to resources in the spatial modelling of bat foraging habitat. PLoS ONE 6(4):e19227.

Rambaldini, D.A. 2003. Habitat use and roost selection by Pallid Bats (*Antrozous pallidus*) in the Okanagan Valley. Year 2 of 2.Progress report for the B.C. Habitat Conservation Trust Fund. Continuing Project File #8-218.

Rambaldini, D.A. 2006. Behavioural ecology of Pallid Bats (Chiroptera: *Antrozous pallidus*) in British Columbia. Osoyoos (Nk'Mip) Indian Band, Oliver, BC, B.C. Ministry of Environment, Penticton, BC, and Canadian Wildlife Service, Delta, BC.

Rasheed, S.A., and S.L. Holroyd. 1995. Roosting habitat assessment and inventory of bats in the Mica Compensation Area. Prepared for BC Hydro and the B.C. Ministry of Environment, Lands and Parks, Nelson, BC. 77pp.

Resources Inventory Standards Committee (RISC). 1998. Inventory methods for bats. Standards for components of British Columbia's biodiversity No. 20. Version 2.0. Prepared by B.C. Ministry of Environment, Lands and Parks, Resources Inventory Branch for the Terrestrial Ecosystems Task Force, Resources Inventory Committee. Original version prepared by P.F.J. Garcia and R.M.R. Barclay. 58pp. [http://www.for.gov.bc.ca/hts/risc/pubs/tebiodiv/bats/assets/bats.pdf]

Resources Inventory Standards Committee (RISC). 2003. Karst inventory standards and vulnerability assessment procedures for British Columbia. Version 2.0. Prepared by B.C. Ministry of Forests Research Branch for the Karst Task Force, Resources Inventory Standards Committee.123 pp.

Roberts, F., and A. Roberts. 1996. Habitat selection by Townsend's Big-eared Bats. Unpublished report for the B.C. Ministry of Environment.

Ross, A. 1967. Ecological aspects of the food habits of insectivorous bats. Proceedings of the Western Foundation of Vertebrate Zoology 1:204–263.

Ruell, J.C. 2000. Factors influencing windthrow in balsam fir forests: from landscape studies to individual tree studies. Forest Ecology and Management 135:169–178.

Rydell, J., A. Entwistle, and P.A. Racey. 1996. Timing of foraging flights of three species of bats in relation to insect activity and predation risk. Oikos, 76: 243–252.

Rydell, J., and P.A. Racey. 1995. Street lamps and the feeding ecology of insectivorous bats. Symposium of the Zoological Society of London 67:291–307.

Sarell, M. 2004*a*. Fringed Myotis, *Myotis thysanodes*. Accounts and measures for managing Identified Wildlife – Accounts V. 2004. B.C. Ministry of Water, Land and Air Protection, Victoria, BC. 7pp. [http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Mammals/m_fringedmyotis.pdf]

Sarell, M. 2004*b*. Spotted Bat, *Euderma maculatum*. Accounts and measures for managing Identified Wildlife – Accounts V. 2004. B.C. Ministry of Water, Land and Air Protection, Victoria, BC. 7pp. [http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Mammals/m_spottedbat.pdf]

Sarell, M.J., and A. Haney. 2000. Habitat use models for three bat species using predictive ecosystem modelling in the Merritt Forest District. Prepared for Keystone Consulting and the Nicola Innovative Forestry Society, Merritt, BC.

Sarell, M.J., and J. Luoma. 1994. Bats in British Columbia. Prepared for B.C. Environment, the B.C. Habitat Conservation Trust Fund, The Nature Trust of B.C., and Bat Conservation International. 6pp.

Sasse, D.B., and P.J. Pekins. 1996. Summer roosting ecology of Northern Long-Eared Bats (*Myotis septentrionalis*) in the White Mountain National Forest. Pp. 91–101 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Saunders, M.B., and R.M. Barclay. 1992. Ecomorphology of insectivorous bats: a test of predictions using two morphologically similar species. Ecology 73:1335–1345.

Schaefer, V. 2003. Green links and biodiversity – an experiment in connectivity. Institute of Urban Ecology, Douglas College, New Westminster, BC. [http://planet.botany.uwc.ac.za/NISL/Conservation%20Biology/Conservation_CCT/2c_schae.pdf]

Schaeffer, L., L. Datchkoff, S. Bennett, and M. Sarell. 2002. Biodiversity inventory within the ICHxw at Fort Shepherd. Final report. Prepared for the Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC.

Schowalter, D.B., W.J. Dorward, and J.R. Gunson. 1978. Seasonal occurrence of Silver-haired Bats (*Lasionycteris noctivagans*) in Alberta and British Columbia. Canadian Field-Naturalist 92:288–291.

Schowalter, D.B., and J.R. Gunson. 1979. Reproductive biology of the Big Brown Bat (*Eptesicus fuscus*) in Alberta. Canadian Field-Naturalist 93:48–54.

Seidman, V.M., and C.J. Zabel. 2001. Bat activity along intermittent streams in Northwestern California. Journal of Mammalogy 82:738–747.

Shump, K.A., and A.U. Shump. 1982*a*. *Lasiurus borealis*. Mammalian Species 183:1–6

Shump, K.A., Jr., and A.U. Shump. 1982*b*. *Lasiurus cinereus*. Mammalian Species 185:1–5.

Simpson, M.R. 1993. *Myotis californicus*. Mammalian Species 428:1–4.

Skalak, S.L., R.E. Sherwin, and R.M. Brigham. 2012. Sampling period, size and duration influence measures of bat species richness from acoustic surveys. Methods in Ecology and Evolution 3(3):490–502.

Smyth, M. 1999. Final report on bat study. Colony Farm Regional Park. Prepared for the Greater Vancouver Regional District Parks Department, Vancouver, BC. 47pp.

Smyth, M.S. 2000. A maternity colony of Townsend's Big-eared Bats, *Corynorhinus townsendii*. M.Sc. Thesis, University of British Columbia, Vancouver, BC. 102pp.[https://circle.ubc.ca/bitstream/id/25662/ubc_2000-0271.pdf]

Summerville, K.S., and T.O. Crist. 2004. Contrasting effects of habitat quantity and quality on moth communities in fragmented landscapes. Ecography 27(1):3–12.

Swengel, A.B. 2001. A literature review of insect responses to fire, compared to other conservation managements of open habitat. Biodiversity and Conservation 10(7):1141–1169.

Swier, V.J. 2003. Distribution, roost site selection, and food habits of bats in eastern South Dakota. M.S. Thesis, South Dakota State University, Brookings, SD. 105pp.

Swystun, M.B., J.M. Psyllakis, and R.M. Brigham. 2001. The influence of residual tree patch isolation on habitat use by bats in central British Columbia. Acta chiropterologica *3*(2):197–201.

Thies, M.L., and K. McBee. 1994. Cross-placental transfer of organochlorine pesticides in Mexican free-tailed bats from Oklahoma and New Mexico. Archives of Environmental Contamination and Toxicology 27(2):239–242.

Thomas, D.W. 1988. The distribution of bats in different ages of Douglas-fir forests. Journal of Wildlife Management 52:619–626.

Thomas, D.W. 1995. Hibernating bats are sensitive to nontactile human disturbance. Journal of Mammalogy 76:940–946.

Thomas, D.W., M. Dorais, and J-M, Bergeron. 1990. Winter energy budgets and cost of arousals for hibernating Little Brown Bats *Myotis lucifugus*. Journal of Mammalogy 71(3):475–479.

Thomson, B. 2002. Australian Handbook for the Conservation of Bats in Mines and Artificial Cave-bat Habitats. Published by Australian Centre for Mining Environmental Research, Melbourne, Australia. 65 pp.

Throgmartin, W.E., C.A. Sanders-Reed, J.A. Szymanski, P.C. McKann, L. Pruitt, R.A. King, M.C. Runge, and R.E. Russell. 2013. White-nose syndrome is likely to extirpate the endangered Indiana bat over large parts of its range. Biological Conservation 160:162–172.

United States Fish and Wildlife Service (USFWS). 2011. Indiana Bat Section 7 and Section 10 Guidance for Wind Energy Projects, Revised 26 October 2011. 63pp.

[http://www.fws.gov/midwest/endangered/mammals/inba/pdf/inbaS7and10WindGuidanceFinal26Oct2011.pdf]

United States Fish and Wildlife Service (USFWS). 2012. Forest Service extends closure of abandoned mines and caves as new studies indicate 5.5 million bats have died. Closure seeks to protect bat species from white-nose syndrome. U.S. Forest Service, Rocky Mountain Region, Golden, CO. News Release. 2pp. [http://www.whitenosesyndrome.org/sites/default/files/files/nr_wnsclosureorder_final_7-31-12.pdf]

United States Fish and Wildlife Service (USFWS). 2013. About White-nose syndrome. [http://www.whitenosesyndrome.org/about-white-nose-syndrome accessed December 2014].

Unger, L., and A.J. Stewart. 1992. Forest insect and disease conditions: Nelson Forest Region 1991. Canada Forest Service, Nanaimo, BC and Pacific Forestry Research Centre, Victoria, BC. Forestry Insect Disease Survey Report 92-3.

Valdez, E.W., and P.M. Cryan. 2009. Food habits of the Hoary Bat (*Lasiurus cinereus*) during spring migration through Mexico. Southwestern Naturalist 54:195–200.

van den Driessche, R., M. Mather, and T. Chatwin. 2000. Habitat selection by bats in temperate old-growth forests, Clayoquot Sound, British Columbia. Pp. 313–320 *in* L.M. Darling, ed. Proceedings of a conference on the biology and management of species and habitats at risk, Kamloops, B.C., 15–19 February 1999. Vol. 1. B.C. Ministry of Environment, Lands and Parks, Victoria, BC and University College of the Cariboo, Kamloops, BC 490 pp.

van Zyll de Jong, S. 1985. Handbook of Canadian mammals. 2. Bats. National Museum of Canada, Ottawa, ON. 212pp.

Verant, M.L., Meteyer, C.U., Speakman, J.R., Cryan, P.M., Lorch, J.M. and Blehert, D.S., 2014. White-nose syndrome initiates a cascade of physiologic disturbances in the hibernating bat host. BMC physiology, 14(1), p.1.

Verboom, B., and H. Huitema. 1997. The importance of linear landscape elements for the pipistrelle, *Pipistrellus pipistrellus* and the serotine bat, *Eptesicus serotinus*. Landscape ecology, 12:117-125.

Verboom, B., and K. Spoelstra. 1999. Effects of food abundance and wind on the use of tree lines by an insectivorous bat, *Pipistrellus pipistrellus*. Canadian Journal of Zoology 77:391–1401.

von Frenckell, B., and R.M.R. Barclay. 1987. Bat activity over calm and turbulent water. Canadian Journal of Zoology 65:219–222.

Vonhof, M.J. 1996. A comparison of the roost-site preferences of Big Brown Bats (*Eptesicus fuscus*) and Silver-haired Bats (*Lasionycteris noctivagans*) in the Pend d'Oreille Valley in southern British Columbia. Pp. 62–80 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Vonhof, M.J., and R.M.R. Barclay. 1996a. Bats and trees. B.C. Ministry of Forests, Nelson Region, Nelson, BC. Extension Note 027.

Vonhof, M., and R.M.R. Barclay. 1996b. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology 74:1797–1805.

Vonhof, M., and R.M.R. Barclay. 1997. Use of tree stumps as roosts by the Western Long-eared Bat. Journal of Wildlife Management 61:674–684.

Vonhof, M.J., and J.C. Gwilliam. 2000. A summary of bat research in the Pend d'Oreille Valley in southern British Columbia. Prepared for the Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC.

Vonhof, M.J., and L.C. Wilkinson. 1999. Roosting habitat requirements of the Northern Long-eared Bat (*Myotis septentrionalis*) in the boreal mixedwood forest of northeastern British Columbia: year 2. Prepared for the B.C. Ministry of Environment, Lands and Parks, Victoria, BC. 87pp.

Vonhof, M.J., and L.C. Wilkinson. 2000. A summary of roosting requirements of Northern Long-eared Myotis in northeastern British Columbia. Pp. 459–460 *in* L.M. Darling, ed. Proceedings of a conference on the biology and management of species and habitats at risk, Kamloops, B.C., 15–19 February 1999. Vol. 1. B.C. Ministry of Environment, Lands and Parks, Victoria, BC and University College of the Cariboo, Kamloops, BC 490pp.

Wai-Ping, V., and M.B. Fenton. 1989. Ecology of the Spotted Bat (*Euderma maculatum*) roosting and foraging behaviour. Journal of Mammalogy 70:617–622.

Waldien, D.L., J.P. Hayes, and E.B. Arnett. 2000. Day-roosts of female Long-eared Myotis in western Oregon. Journal of Wildlife Management 64:785–796.

Walsh, A.L., and S. Harris. 1996. Foraging habitat preferences of Vespertilionid bats in Britain. Journal of Applied Ecology 33:508–518.

Warman. L., S. Robertson, A. Haney, and M. Sarell. 1998. Habitat capability and suitability models for 34 wildlife species using terrestrial ecosystem mapping (1:20,000) in the South Okanagan and Lower Similkameen study area and forest cover mapping (1:20,000) in the Penticton Forest

District. B.C. Ministry of Environment, Lands and Parks, Penticton, BC. 68pp.

Warner, R.M. 1985. Interspecific and temporal dietary variation in an Arizona bat community. Journal of Mammalogy 66:45–51.

Warner, R.M., and N.J. Czaplewski. 1984. *Myotis volans*. Mammalian Species 224:1–4.

Watkins, L.C. 1977. *Euderma maculatum*. Mammalian Species 77:1–4.

Weller, T.J., and C.J. Zabel. 2001. Characteristics of Fringed Myotis day roosts in northern California. Journal of Wildlife Management 65:489–497.

Whitaker, J.O., Jr. 1995. Food of the Big Brown Bat, *Eptesicus fuscus,* from maternity colonies in Indiana and Illinois. American Midland Naturalist 134:346–360.

Whitaker, J.O., Jr., and B. Lawhead. 1992. Foods of *Myotis lucifugus* in a maternity colony in central Alaska. Journal of Mammalogy 73(3):646–648.

Whitaker, J.O., Jr., C. Maser, and L.E. Keller. 1977. Food habits of bats of western Oregon. Northwest Science 51(1):46–55.

Whitaker, J.O., Jr., C. Maser, L.E. Keller, and S.P Cross. 1981. Food habits of eastern Oregon bats, based on stomach and scat analyses. Northwest Science 55:281–292.

Whitham, T.G., K.D. Floate, G.D. Martinsen, E.M. Driebe, and P. Keim. 1996. Ecological and evolutionary implications of hybridization: *Populus*-herbivore interactions. Pp. 247–275 *in* R.H. Stettler, ed. Biology of *Populus* and its implications for management and conservation. NRC Research Press, Ottawa, ON.

Wilcox, A., L. Warnecke, J. Turner, L. McGuire, J. Jameson, T. Bollinger, V. Misra, and C. Willis. 2013. The effect of *Geomyces destructans* on the behaviour of hibernating Little Brown Bats. Presentation to the North American Symposium on Bat Research, Puerto Rico.

Wilkinson, L.C. and R.M.R. Barclay. 1997. Differences in the foraging behaviour of male and female Big Brown Bats (*Eptesicus fuscus*) during the reproductive period. *Ecoscience* 4:279–285.

Wilkinson, G.S., and J.M. South. 2002. Life history, ecology and longevity in bats. Aging Cell 1:124–131.

Willis, C.K.R., and R.M. Brigham. 2005. Physiological and ecological aspects of roost selection by reproductive female Hoary Bats (*Lasiurus cinereus*). Journal of Mammalogy 86:85–94. [http://www.willisbatlab.org/uploads/8/0/0/6/8006753/willis_brigham_2005_hoary_roosts.pdf]

Willis, C.K.R, K.A. Kolar, A.L Karst, M.C. Kalcounis-Ruepell, and R.M. Brigham. 2003. Medium- and long-term reuse of trembling aspen cavities as roosts by Big Brown Bats (*Eptesicus fuscus*). Acta Chiropterologica 5:85–90.

Wilson, J.M., and R.M.R. Barclay. 2006. Consumption of caterpillars by bats during an outbreak of western spruce budworm. American Midland Naturalist 155(1):244–249.

Wilson, J., J. Reimer, C.L. Lausen, and D. Allaire. 2015. Diversity and distribution of bats in the Northwest Territories. Northwestern Naturalist 95:197-218.

Woodsworth, G.C., G.P. Bell, and M.B. Fenton. 1981. Observations of the echolocation, feeding behaviour, and habitat use of *Euderma maculatum* (Chiroptera: Vespertilionidae) in southcentral British Columbia. Canadian Journal of Zoology 59:1099–1102.

Personal communication

Burles, D., Wildlife Biologist/Parks Canada Biologist (retired), Kamloops, BC

Craig, J. Silverwing Consulting, Nelson, BC

Griffiths, P. Cave and Karst Resource Management Services, Gold River, BC.

Hickey, B. Program Leader Education/Research Scientist, St. Lawrence River Institute of Environmental Sciences, 2 St. Lawrence Dr., Cornwall, ON K6H 4Z1

Horne, G., Parks Canada, Jasper National Park of Canada, Box 10, Jasper, AB, T0E 1E0

Lausen, C. Birchdale Ecological Ltd., PO Box 606 Kaslo, BC V0G 1M0

Palmer, C. Hemmera. Suite 250, 1380 Burrard St., Vancouver, BC V6Z 2H3

Sarell, M. Ophiuchus Consulting, Oliver, BC

Wilkinson, L. Reg. Endangered Species Specialist, Alberta Fish and Wildlife Division, Government of Alberta, # 203, 111–54 St., Edson, AB T7E 1T2

Wilson, J. Department of Environment and Natural Resources, Government of Northwest Territories, P.O. Box 1320, 5th Floor, Scotia Centre, Yellowknife, NWT X1A2L9

Appendix A: Literature Review of Distance Travelled and Flight Heights of Bats in British Columbia

The following summaries for each of British Columbia's bat species focus primarily on reproductive females, and are a compilation of the following information from all parts of each species' range:

1. distance travelled from capture location to subsequent roost (including maximum and mean values and ranges of values where available);
2. distance travelled from the day-roost to the foraging area (including maximum and mean values and ranges of values where available);
3. size of foraging areas (maximum and core areas and mean values and ranges are given where available);
4. distance travelled between successive day-roost locations (including mean values and range of values where available); and
5. distance travelled between summer and winter habitats (where available).

The classification of short-, medium-, and long-range flyers is for management purposes during the summer breeding period only. Species are listed within these three groups based on average distance individuals fly from the day-roost to foraging areas and/or the average distance measured between capture location and subsequent day-roost location during the summer breeding period.

Some of these bat species exhibit very different flight behaviour between summer and winter habitats. A brief description of flight distances by species (where available) is included below because this information shows the flight capabilities of various bat species. The summer classification of flight behaviour reflects observed behaviours.

Short-range Flyers

Foraging flight distances of short-range flyers tend to be approximately 1 kilometre or less, but these bats can range up to 5–6 kilometres from their day-roosts when foraging.

Eight species are included in this group: Western Small-footed Myotis (*Myotis ciliolabrum*), Californian Myotis (*Myotis californicus*), Long-eared Myotis (*Myotis evotis*), Keen's Myotis (*Myotis keenii*), Northern Myotis (*Myotis septentrionalis*), Fringed Myotis (*Myotis thysanodes*), Long-legged Myotis (*Myotis volans*), and Pallid Bat (*Antrozous pallidus*).

Western Small-footed Myotis and Californian Myotis

The two smallest bats in British Columbia, Western Small-footed Myotis and Californian Myotis (Nagorsen and Brigham 1993), make relatively short movements between day-roosts and foraging areas (Brigham et al. 1997; Lausen 2007; ASRD and ACA 2008).

Western Small-footed Myotis in Alberta moved 4–580 metres (m) (146 ± 23 m [mean ± SD]) between the site of first capture and their subsequent day-roost location (Lausen 2007; ASRD and ACA 2008). In Oregon, the mean distance Western Small-footed Myotis travelled between capture location and subsequent day-roost was 4.4 kilometres (range = 0.3–10.5 kilometres; n = 9 reproductive females) (Rodhouse and Wright 2010). Californian Myotis in Nelson, B.C. moved 500–3140 m (1529 ± 910 m [mean ± SD]; n = 8) between capture site and subsequent day-roosts (Brigham et al. 1997).

Western Small-footed Myotis showed high fidelity to their foraging areas over agricultural fields and in riparian areas located a mean distance of 6 kilometres from their day-roost (n = 9 reproductive females; range of foraging distances = 3–12 kilometres) (Rodhouse and Wright 2010).

Movements between successive roosts by Western Small-footed Myotis were very small: 6.4–106 m (mean ± SD, 45 ± 6 m); all roosts were located in a complex of geologically based crevice roosts within the same riverbank (Lausen 2007).

Based on studies of gene flow, Lausen (2007) estimated that Western Small-footed Myotis likely move less than 200 kilometres to winter hibernation sites; male bats may travel 70–134 kilometres when dispersing from natal colonies to winter hibernation or fall swarming sites.

Long-eared Myotis, Keen’s Myotis, and Northern Myotis

The three Long-eared Myotis species (Keen’s Myotis, Northern Myotis, and Long-eared Myotis) are genetically distinct but morphologically and functionally quite similar (van Zyll de Jong 1979; van Zyll de Jong and Nagorsen 1994).

On Haida Gwaii, Keen’s Myotis were observed up to 500 metres from the day-roost (D. Burles pers. comm. in Chatwin 2004). The longest movement from the day-roost recorded for Keen’s Myotis in summer is 1 kilometre (Clayoquot Sound, B.C.) (Mather et al. 2000).

Northern Myotis also appear to have relatively small foraging and roosting home ranges. Relatively short foraging flights of 1.1 kilometres from the day-roost were recorded in an area with fragmented forest on Prince Edward Island (Henderson and Broders 2008). Larger foraging home ranges have been recorded in areas with larger, contiguous tracts of forest. Foraging areas in these habitats were 65 hectares (ha) in West Virginia (Owen et al. 2003) and 46 ha in New Brunswick (Broders et al. 2006), whereas foraging areas in fragmented forest were smaller (minimum foraging area = 6.09 ± 5.8 3 ha [mean ± SD]; n = 17) (Henderson and Broders 2008, Prince Edward Island).

Long-eared Myotis may venture a little farther than Northern or Keen's Myotis; the longest recorded foraging flight from the day-roost was 2.4 kilometres in western Oregon (Waldien and Hayes 2001). Generally, Long-eared Myotis have been observed foraging only 100–600 m from the day-roost. The following distances have been recorded in various regions: < 200 m in northeastern Washington (Rancourt et al. 2005); average 518 m in western Oregon (Waldien and Hayes 2001); 600 m in California (Pierson 1998; Buseck and Keinath 2004); and 100–500 m in the Alberta prairies (Chruszcz 1999). Proximity to water appears to be important to Long-eared Myotis (Waldien and Hayes 2001).

Long-eared Myotis in northeastern Washington moved relatively short distances between roosts (148.9 ± 46.3 m [mean ± SE]; n = 26); all but one of these roosts were in rock crevices (Rancourt et al. 2005). In Nelson, B.C., Long-eared Myotis moved an average of 61 ± 17.7 m between roosts (mean ± SD; n = 2 adult males) (Vonhof and Barclay 1996).

In Missouri, Keen's Myotis moved 56 kilometres from summer habitats to winter hibernation sites (note: this species has been reclassified as Northern Myotis [*Myotis septentrionalis*]) (Caine 1978).

Fringed Myotis

Female Fringed Myotis have not been recorded making long-distance movements during the reproductive period; therefore, they may be classed as either short-range or mid-range flyers. In the Pacific Northwest, reproductive females moved only 1.6 ± 0.34 kilometres (mean ± SE; n = 23) between capture locations and subsequent roost sites (Lacki and Baker 2007).

Radio-tagged females in Colorado consistently foraged between their day-roost in a cliff and a water source 1 kilometre away (Adams and Hayes 2008). In California, Fringed Myotis moved up to 8 kilometres between day-roosts and foraging areas (Keinath 2003, 2004). Based on wing morphology, this species likely makes longer flights than the Long-eared Myotis (Keinath

2003); however, its wing morphology also suggests that it may be classed as a gleaning bat species, like the Long-eared Myotis (Lacki et al. 2007).

Female Fringed Myotis in the Pacific Northwest moved 0.55 ± 0.12 kilometre (mean ± SE; range = 0.01–3.3 kilometre; n = 22) between successive roosts; includes movements between rock roosts as well as movements between tree roosts (Lacki and Baker 2007).

Long-legged Myotis

One adult female Long-legged Myotis in Nelson, B.C. moved up to 2.95 kilometres between the day-roost and foraging site (Vonhof and Barclay 1996). Johnson et al. (2007) calculated the following home range sizes for this species in Idaho—males: 647 ± 354 ha (mean ± SE; n = 8); pregnant females: 448 ± 78.7 ha (mean ± SE; n = 10); lactating females: 304 ± 53.8 ha (mean ± SE; n = 10). Core area sizes were as follows—males: 103 ± 574 ha (mean ± SE; n = 8); pregnant females: 69.3 ± 11.1 ha (mean ± SE; n = 10); lactating females 51.5 ± 11.4 ha (mean ± SE, n = 10) (Johnson et al. 2007). There was no statistical difference in home range size based on sex or reproductive condition, but males had the largest variance in home range size; both the smallest (16.5 ha) and the largest home range sizes (3029 ha) were recorded for males (Johnson et al. 2007). Based on these home range sizes, and assuming the home range was circular, with the day-roost(s) situated at the centre, the foraging distances for Long-legged Myotis in Johnson et al.'s (2007) study would equal a radius of approximately 1–2 kilometres (i.e., a 1-kilometre radius circle has an area of 314 hectare; a 2-kilometre radius circle has an area of 1257 hectares); males may make longer flights.

Mid-slope landscape positions were important to Long-legged Myotis in Idaho: roost areas were most often located at these sites, and abundance of moth prey was the highest (Johnson et al. 2007).

In central Oregon, the average distances Long-legged Myotis travelled between day-roosts were 412.5 m (n = 11) and 3258 m (n = 1); the area that encompassed all day-roosts (n = 15) and one night-roost covered 6391 ha (Ormsbee 1996). In Nelson, B.C., two adult females moved 28 ± 5 m (mean ± SD) between roosts; an adult male moved 206 m (Vonhof and Barclay 1996).

Pallid Bat

Pallid Bats generally are short-range flyers. Flights have been recorded within 3 kilometres of the roost (Bell 1982 [New Mexico]; Johnston and Fenton 2001 [California]).

Reproductive females in Oregon moved 0.41 kilometres from the capture site to subsequent day-roosts; however, late season females (post-lactating) ranged up to 10 kilometres from their capture site to their day-roost location (Rodhouse and Wright 2010).

In a two-year study in the Okanagan Valley, B.C., seven radio-tagged males and one radio-tagged female foraged within 1.5 kilometres of their day-roosts (Rambaldini 2006). In Northern California, Pallid Bat summer foraging movements in a coniferous forest-dominated habitat were slightly larger than those recorded in previous studies (longest distances moved 2.2–4.7 kilometres), but were still within the range of a short-range flying bat (Baker et al. 2008). In another California study, Pallid Bats travelled more than 4 kilometres to foraging areas, and the maximum distance flown by a lactating female was 6.7 kilometres (O'Shea and Vaughn 1977). Even though this species uses a gleaning foraging strategy, it is capable of long-range movements. Travel distances of 11 kilometres and 30 kilometres have been documented in California (Davis 1966; Brown et al. 1997; Baker et al. 2008); however, these could have been movements made by males or movements to wintering sites.

In northern California, lactating females had the smallest foraging home ranges (156 ± 88 ha [mean ± SE]; n = 6) compared to those of pregnant females (317 ha; n = 1), post-lactating females (597 ± 269 ha [mean ± SE]; n = 2), non-reproductive females (243 ha; n = 1), and non-reproductive males (412 ± 300 ha [mean ± SE]; n =2) (Baker et al. 2008).

In northern California, lactating females moved the farthest from their day-roost to their foraging areas (2.45 ± 0.845 kilometres [mean ± SE]; n = 6), compared to pregnant females (0.893 kilometres; n = 1), post-lactating females (0.21 kilometres; n = 2), and non-reproductive females (0.180 kilometres; n = 1) (Baker et al. 2008). Distance to water from the day-roost ranged from 300 to 671 m; pregnant and lactating females roosted closest to water (300 and 358 m, respectively) (Baker et al. 2008).

Mid-range Flyers

Mid-range flyers tend to fly more than 2 kilometres to forage but generally range 5–8 kilometres from their day-roosts.

Four species are included in this group: Little Brown Myotis (*Myotis lucifugus*), Yuma Myotis (*Myotis yumanensis*), Red Bat (*Lasiurus borealis*), and Townsend's Big-eared Bat (*Corynorhinus townsendii*).

Little Brown Myotis

Summer movements of 1–10 kilometres between day-roosts and foraging areas have been commonly recorded for Little Brown Myotis (Anthony and Kunz 1977; Fenton and Barclay 1980; Rainey 2005; Kunz and Reichard 2010); however, in the Pacific Northwest, Little Brown/Yuma Myotis breeding females made regular one-way commutes of 10–15 kilometres to foraging areas (Falxa 2005; Towada and Falxa 2007).

On an island in Quebec, home range sizes of lactating females were almost half those of pregnant females (17.6 ± 9.1 ha [mean ± SD] versus 30 ± 15 ha [mean ± SD]) (Henry et al. 2002). Core home ranges sizes were also smaller for lactating females (5.7 ± 3.5 ha [mean ± SD, n=22]) than for pregnant females (11.6 ± 6.7 ha [mean ± SD, n=22]) (Henry et al. 2002). In this study, home range was defined as the area within the contour with 90% of recorded radio-telemetry positions; the core home range was the area within the 50% contour of these observations (Henry et al. 2002).

In New England, Little Brown Myotis adults flew 37 kilometres from a release site to their day-roost (labelled "homing" by Davis and Hitchcock [1965]). Juvenile Little Brown Myotis were not capable of this homing behaviour and would either find an alternative day-roost at the release site or disperse elsewhere (Davis and Hitchcock 1965).

Distances moved between summer and winter habitats were 50–200 kilometres in Ontario (Fenton and Barclay 1980) and 1.6–80.5 kilometres in New England (Davis and Hitchcock 1965). In New England, one female travelled 128 kilometres in three days (averaging 43.5 kilometres per night) (Davis and Hitchcock 1965).

Yuma Myotis

In Squilax, B.C., Yuma Myotis were observed flying 4 kilometres between roosting and foraging areas (Nagorsen and Brigham 1993). In a residential area of California, Yuma Myotis moved an average of 1130 m between roosts; lactating females were captured an average of 2 kilometres from their day-roost sites (Evelyn et al. 2004).

Red Bat

Red Bats (*Lasiurus borealis*) are one of the most studied species in terms of day-roosting ecology and telemetry studies (Carter and Menzel 2007). Home range sizes or commuting distances between roosting and foraging habitat may be influenced by the availability of high-density prey patches, such as around streetlights (Hickey and Fenton 1990). Larger home range sizes may be a result of fragmented landscapes, landscape context (amount and types of development), or absence of high-density prey patches (Elmore et al. 2004; Carter and Menzel 2007).

Reproductive females in Kentucky tended to repeatedly visit the same foraging areas, and most foraging areas included a permanent water source that all bats visited within the first hour of the foraging period; they also foraged mostly in forested habitats (Elmore et al. 2004; Carter and Menzel 2007). Females may have greater long-term site fidelity to roosting and foraging sites than do males; one female Red Bat was captured three years in a row foraging over the same stream pool (Perry 2011).

In Arkansas, male Red Bats moved 1.6 kilometres from capture site to subsequent roost site and made subsequent moves of 0.6 and 0.3 kilometres (Saugey et al. 1998). Red Bats in a managed pine forest travelled a maximum distance of 0.7–2.1 kilometres from the roost; adult females travelled a maximum of 1.2 ± 0.34 kilometres (mean ± SE; n = 7) (Elmore et al. 2004). In South Carolina, the mean distance between capture location and the subsequent roost tree was 806 ± 145.42 m ([mean ± SD]; range 42.7–2870 m; n = 32) (Leput 2004).

Various studies on Red Bats have reported foraging areas ranging from a minimum of 29.9 ha (Walters et al. 2007) to a maximum of 925 ha (Carter and Menzel 2007). In a managed pine landscape in Mississippi, the mean size of foraging areas for both sexes (including adults and juveniles) ranged from 62.6 to 146.7 ha; adult females had average foraging areas of 82.1 ± 31.8 ha (mean ± SE; n = 7) (Elmore et al. 2004). In an area at an urban-rural interface in Indiana, Red Bat home ranges averaged 67.9 ± 38.01 ha (mean ± SD; n = 13) and varied from 29.9 to 142.6 ha (this included a pooled sample of reproductive and post-reproductive females and juveniles, but the high and low of the range were both associated with pregnant females) (Walters et al. 2007). Average home range size for males and females in Kentucky was 334 ha (female foraging areas ranged from 113 to 850 ha; male foraging areas ranged from 134 to 925 ha) (Carter and Menzel 2007). In South Carolina, Red Bats had home ranges of 453 ha, on average (Carter 1998).

Recorded movements of Red Bats between day-roosts and foraging areas range from 0.42 kilometres (Walters et al. 2007) to 7.4 kilometres (Carter and Menzel 2007). In a Kentucky forest, females moved 1.2–5.5 kilometres from the day-roost to forage (in late summer the average distance was 1.55 kilometres); males moved 1.4–7.4 kilometres to forage (Hutchinson and Lacki 1999). In another Kentucky study, a female with non-volant young spent 2.6 ± 0.2 h/night (mean ± SD) in flight or roosting at an alternative roost; she foraged within 3.2 kilometres of the roost on nine nights

(Hutchinson and Lacki 2000). Females without non-volant young consistently flew farther than this and were regularly out of range of the receiver (Hutchinson and Lacki 2000). In Ontario, Red Bats remained within 1 kilometre of their roosts while foraging around street lights (Hickey and Fenton 1990). Similarly, in an urban-rural interface area in Indiana, the mean maximum distance flown by Red Bats from day-roost to foraging area was 0.95 kilometres, and ranged from 0.42 to 1.76 kilometres (pooled reproductive females and juveniles, but the high and low values were both associated with pregnant females) (Walters et al. 2007).

Townsend's Big-eared Bat

Townsend's Big-eared Bat also uses gleaning as a foraging strategy and is known as a slow, manoeuvrable flyer. Radio-tagged Townsend's Big-eared Bats have been followed in a number of areas within their range. The farthest they have been recorded moving between day-roosts and foraging sites is 13 kilometres (California [Pierson et al. 1999]), but generally, recorded foraging distances have been much shorter than this; e.g., 2–8 kilometres in central Oregon (Dobkin et al. 1995), 6.4 kilometres in Nevada (post lactating females [Bradley 1996]), 5 kilometres on Santa Cruz Island, California (Brown et al. 1994), 3.2 kilometres in coastal California (post-lactating females [Fellers and Pierson 2002]), and 1–4.2 kilometres (for a Townsend's Big-eared Bat subspecies, the Ozark Big-eared Bat; lactating and post-lactating females [Clark et al. 1993]). In British Columbia, Townsend's Big-eared Bats from a maternity colony in a horse stable spent most of their foraging time within 500 m of the roost at the edge of a forested area (Smyth 2000).

Distances, time spent foraging, and area covered while foraging differ according to sex, reproductive condition, and age (Clark et al. 1993). In Kentucky, Townsend's Big-eared Bat foraging areas increased from 60 to 263 ha between pregnancy and the post-lactation period (Adam et al. 1994).

Generally, Townsend's Big-eared Bat is characterized as a sedentary species; movements from summer to winter habitats range between 10 and 65 kilometres (Humphrey and Kunz 1976; Kunz and Martin 1982; Nagorsen and Brigham 1993). Assessments of Townsend's Big-eared Bat populations have shown that where areas of suitable habitat are restricted, there is low gene flow between populations, and because this species does not make long flights between areas of suitable habitat, it is appropriate to use a meta-population model for Townsend's Big-eared Bat (Gruver and Keinath 2006).

Long-range Flyers

Long-range flyers tend to make foraging flights that are generally 10 kilometres or more from their day-roosts.

Four species are included in this group: Hoary Bat (*Lasiurus cinereus*), Big Brown Bat (*Eptesicus fuscus*), Spotted Bat (*Euderma maculatum*), and Silver-haired Bat (*Lasionycteris noctivagans*).

Hoary Bat

The Hoary Bat is the largest bat species in Canada (Nagorsen and Brigham 1993). It is known for its high, fast, direct flights, and has been clocked up to 21.3 kilometres/h (Shump and Shump 1982). Radio-telemetry research in Manitoba indicated that lactating females had a mean foraging flight distance of 6.3 ± 1.0 kilometres (mean ± SD; n = 9); once females had flying young, flight distances were 6.0 ± 1.0 kilometres (mean ± SD; n = 9) (Barclay 1989). The maximum distance recorded for a lactating female was on her first foraging trip of the night, which was a straight-line distance of up to 20 kilometres from the roost; she made subsequent flights from the roost throughout the night (Barclay 1989). Female Hoary Bats forage all night during the reproductive period and make as many as five foraging bouts per night before returning to their day-roosts 30–45 minutes before dawn (Barclay 1989).

Hoary Bats are long-distance migrators; they, fly from northern Canada to as far south as Mexico (Nagorsen and Brigham 1993; Cryan 2003). Based on isotope analysis, it is estimated that migratory flights are 2000–3000 kilometres each way (Cryan et al. 2004).

Big Brown Bat

Big Brown Bats have been recorded travelling 0.45–53 kilometres between day-roosts and foraging areas (Beer 1955; Betts 1996). A maximum flight distance of 53 kilometres was recorded in Minnesota and Wisconsin (Beer 1955). In northeastern Oregon, Big Brown Bat roost trees were 0.45–3.8 kilometres from capture sites, and the maximum recorded distance between roosts for two individuals that used four different tree roosts was 2.1 kilometres (Betts 1996). In South Dakota, the mean distance between capture and roost site was 1.5 kilometres (Cryan et al. 2001). In the Okanagan, B.C., commuting distances between day-roost and foraging areas ranged from 1 to 4 kilometres (Brigham 1991). In this same region, the average distance between roost sites and foraging areas was 1.8 kilometres ± 0.1 (mean ± SD; n = 163 flights); in Ontario, it was 0.9 kilometres ± 0.09 (mean ± SD; n = 85 flights) (Brigham 1991). In Alberta, reproductive female Big Brown Bats foraged 20–25 kilometres from their day-roosts along the South Saskatchewan River Valley before returning to the roost (Wilkinson and Barclay 1997).

At an urban-rural interface in Indiana, reproductive Big Brown Bats (including pregnant and lactating females) had foraging areas of 2.70 ± 0.49 km^2 (mean ± SD; n = 4), whereas non-reproductive females had larger foraging ranges of 19.03 ± 5.58 km^2 (mean ± SD; n = 7) (Duchamp et al. 2004). Big Brown Bats appear to tolerate urban development; they readily fly through these areas or use them for foraging habitat (Duchamp et al. 2004).

In Oregon, Big Brown Bats moved 0.83 ± 0.81 kilometres (mean ± SD; n = 5) between successive tree roosts; the longest distance between roosts was 2.1 kilometres (Betts 1996).

Distances travelled between winter hibernation sites and summer foraging areas can be up to 300 kilometres but are usually no more than 80 kilometres (Nagorsen and Brigham 1993). In Minnesota and Wisconsin, this distance ranged from 0.8 to 98.2 kilometres (average 11.9 kilometres, n = 25) (Beer 1955). In Ohio, winter roosts tended to be within 32 kilometres of summer roosts (Brenner 1968).

Spotted Bat

Spotted Bats have been followed 6–10 kilometres one way from their cliff day-roosts to foraging areas (Wai-Ping and Fenton 1989; Nagorsen and Brigham 1993; Sarell 2004). The actual distances flown per night are much longer than this because this species routinely flies in large elliptical patterns over foraging areas, with circuits covering clearings of 1–20 ha and 0.5–3 kilometres apart (Woodsworth et al. 1981; Wai-Ping and Fenton 1989). One Spotted Bat flew over an 8-km^2 area as it searched six different clearings in a ponderosa pine forest (Woodsworth et al. 1981). Another Spotted Bat flew over the same 50-ha area for about 1 hour at a treetop height of 10–30 m above the ground (Woodsworth et al. 1981).

Silver-haired Bat

In Nelson, B.C., a juvenile male Silver-haired Bat travelled up to 4.3 kilometres in forested terrain between capture site and day-roost, four adult females travelled an average of 0.522 kilometres (range = 0.27–0.75 kilometres) between the capture site and their day-roosts, and one adult male moved 150 m between the capture site and day-roost (Vonhof and Barclay 1996). In northeastern Oregon, one Silver-haired Bat roosted 5 kilometres from the capture site (Betts 1996); in another study in this area, the maximum distance travelled from capture site to day-roosts was 23.5 kilometres (n = 15) (Campbell et al. 1996).

In northeastern Oregon, reproductive females moved 35–1100 m between successive roosts (n = 15) (Betts 1998). In Nelson, B.C., the distance travelled between roosts was 183 ± 159.6 m (mean ± SD; n = 3 adult females) (Vonhof and Barclay 1996).

Movements of Silver-haired Bats vary depending on whether the population is migratory or non-migratory (Hirt 2008). Migratory Silver-haired Bats may move hundreds of kilometres (Nagorsen and Brigham 1993) to 1500 kilometres between their summer and winter roosting areas (Hirt 2008; McGuire et al. 2012). In Ontario, migratory Silver-haired Bats were estimated to travel 250–275 km/day and to make a 1500-kilometre flight to their wintering area (McGuire et al. 2012). Silver-haired Bats were captured and observed at migratory stopover during their southward journey at Long Point, Ontario on the edge of Lake Erie where they faced a minimum crossing distance across Lake Erie of 38 kilometres (McGuire et al. 2012). McGuire et al. (2012) assumed that the bats flew this distance directly across the water (rather than circumnavigating the lake). There is evidence that some populations in some parts of their range are non-migratory; specific studies are needed to determine the status of each population (Hirt 2008).

Flight Heights

Much of the information on bat flight heights has been obtained from observations of foraging bats, either through light-tagging, radio-telemetry, or direct observation (Table A-1). Some non-migratory species normally fly close to the ground or stay within forest interiors (e.g., Northern Myotis); they would not be at risk of being killed at wind turbine sites because they do not fly high enough to be hit by the rotors (i.e., more than 10 m above the ground) or to be affected by barotrauma (Kunz et al. 2007; Arnett et al. 2008; Baerwald et al. 2008; Jacques Whitford 2009; Stantec Consulting Ltd. 2010; Jain et al. 2011). However, bats may behave quite differently at the end of the summer breeding season when they are either moving to swarming sites and/or hibernation sites or migrating to their wintering habitat. There is little information on flight heights during these movements (Fleming and Eby 2003).

Table A-1. Flight heights of foraging bats, and their foraging habitats.

Species	Foraging Flight Height	Foraging Habitat Types	Reference
Hoary Bat	High fliers; generally forage above forest canopy (25–35 m above ground) but could forage much higher	Open air foraging; above treetops	Nagorsen and Brigham 1993
Big Brown Bat	5–10 m above water; 30 m above ground	Above treetops	Nagorsen and Brigham 1993; Menzel et al. 2005
Silver-haired Bat	25–35 m	Treetop level and over water	Nagorsen and Brigham 1993; Menzel et al. 2005
Spotted Bat	10–30 m	Above the ground; clearings in the dry bunchgrass-ponderosa pine zone	Woodsworth et al. 1981
Eastern Red Bat	5–10 m	Open air foraging	Nagorsen and Brigham 1993
Long-legged Myotis	Various heights, but will forage above forest canopy, so possibly 35 m or higher	Above water, in forests, above vegetation, above the forest canopy	Nagorsen and Brigham 1993
Little Brown Myotis	50 cm above water surface		Barclay 1991
Yuma Myotis		Over water	Nagorsen and Brigham 1993
Fringed Myotis	5–10 m	In thickets along streams	Nagorsen and Brigham 1993
Long-eared Myotis	1–3 m above the ground and above foliage; 25–35 m in the forest canopy	Forest paths, forest canopy; primarily gleaning but also aerial hawking	Barclay 1991; Nagorsen and Brigham 1993
Keen's Myotis	25–35 m in forest canopy		Nagorsen and Brigham 1993
Northern Myotis	1–3 m	Above the ground just above the understorey in forests	Nagorsen and Brigham 1993
Californian Myotis	< 3 m over water; 25–35 m in the forest canopy	Lake surfaces; poplar groves	Nagorsen and Brigham 1993
Western Small-footed Myotis	1–5 m above the ground; up to 25–35 m (treetop height)	Will hunt over water but more often over rocky bluffs; sometimes riparian, low slopes, agricultural fields	Fenton et al. 1980; Woodsworth 1981; Schowalter and Allen 1981; Holloway and Barclay 2001; Rodhouse and Wright 2010
Townsend's Big-eared Bat	< 5 m	Gleaning off plants and shrubs	Nagorsen and Brigham 1993
Pallid Bat	One study reported flights 1–3 m above ground another 0.1–10 m	Forages close to the ground but also in shrubs and trees	Bell 1982; Nagorsen and Brigham 1993

Literature Cited

Adam, M.D., M.J. Lacki, and T.G. Barnes. 1994. Foraging areas and habitat use of the Virginia Big-eared Bat in Kentucky. Journal of Wildlife Management 58:462-469.

Adams, R.A., and M.A. Hayes. 2008. Water availability and successful lactation by bats as related to climate change in arid regions of western North America. Journal of Animal Ecology 77:1115-1121.

Alberta Sustainable Resource Development (ARSD) and Alberta Conservation Association (ACA). 2008. Status of the Western Small-footed Bat (*Myotis ciliolabrum*) in Alberta. Prepared by C. Lausen and T. Schowalter. Alberta Sustainable Resource Development, Wildlife Status Report No. 64, Edmonton, AB. 24pp.

Anthony, E.L.P., and T.H. Kunz. 1977. Feeding strategies of the Little Brown Bat, *Myotis lucifugus*, in southern New Hampshire. Ecology 58:775–786.

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

Baerwald, E.F., G.H. D'Amours, B.J. Klug, and R.M.R. Barclay. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. Current Biology 18:R695-R696.

Baker, M.D., M.J. Lacki, G.A. Falxa, P.L. Droppelman, R.A. Slack, and S.A. Slankard. 2008. Habitat use of Pallid Bats in coniferous forests of Northern California. Northwest Science 82:269-275.

Barclay, R.M.R. 1989. Effect of reproductive condition on the foraging behavior of female Hoary Bats, *Lasiurus cinereus*. Behavioral Ecology and Sociobiology 24:31-37.

Barclay, R.M.R. 1991. Population structure of temperate zone insectivorous bats in relation to foraging behaviour and energy demand. Journal of Animal Ecology 60:165-178.

Beer, J.R. 1955. Survival and movements of banded Big Brown Bats. Journal of Mammalogy 36:242-247.

Bell, G.P. 1982. Behavioral and ecological aspects of gleaning by a desert insectivorous bat, *Antrozous pallidus* (Chiroptera; Vespertilionidae). Behavioral Ecology and Sociobiology 10:217–223.

Betts, B.J. 1996. Roosting behaviour of Silver-haired Bats (*Lasionycteris noctivagans*) and Big Brown Bats (*Eptesicus fuscus*) in northeast Oregon. Pp. 55–61 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

Betts, B.J. 1998. Variation in roost fidelity among reproductive female Silver-haired Bats in northeastern Oregon. Northwestern Naturalist 79:59–63.

Bradley, P.V. 1996. Foraging activity of adult female Pale Big-eared Bats (*Corynorhinus townsendii pallescens*) in east-central Nevada (Abstract). Bat Research News 37:21.

Brenner, F.J. 1968. A three-year study of two breeding colonies of the Big Brown Bat, *Eptesicus fuscus*. Journal of Mammalogy 49:775–778.

Brigham, R.M. 1991. Flexibility in foraging and roosting behaviour by the Big Brown Bat (*Eptesicus fuscus*). Canadian Journal of Zoology 69:117–121.

Brigham, R.M.R., M.J. Vonhof, R.M.R. Barclay, and J.C. Gwilliam. 1997. Roosting behavior and roost-site preferences of forest-dwelling California Bats (*Myotis californicus*). Journal of Mammalogy 78:1231–1239.

Broders, H.G., G.J. Forbes, S. Woodley, and I.D. Thompson. 2006. Range extent and stand selection for forest-dwelling Northern Long-eared and Little Brown Bats in New Brunswick. Journal of Wildlife Management 70:1174–1184.

Brown, P.E., R.D. Berry, and C. Brown. 1994. Foraging behavior of Townsend's Big-eared Bats (*Plecotus townsendii*) on Santa Cruz Island. Pp. 367–369 *in* W.L. Halvorson and G.J. Maender, eds. Fourth California Islands Symposium, Santa Barbara Museum of Natural History, Santa Barbara, CA. (IN: Pierson et al. 1999 – Species conservation assessment and strategy for Townsend's Big-eared Bat.).

Brown, P.E., R.D. Berry, K. . Miner, and H. Johnson. 1997. Roosting behavior of Pallid Bats *Antrozous pallidus* in the California desert as determined by radio-telemetry. Bat Research News 38:100.

Buseck, R.S., and D.A. Keinath. 2004. Species assessment for Western Long-eared Myotis (*Myotis evotis*) in Wyoming. Prepared for the U.S. Department of the Interior, Bureau of Land Management, Cheyenne, WY. 76pp. [http://www.uwyo.edu/wyndd/_files/docs/reports/speciesassessments/long-earedmyotis-oct2004.pdf]

Caine, W. 1978.Notes on the ecology of *Myotis keenii* (Chiroptera, Vespertilionidae) in eastern Missouri. American Midland Naturalist 102:404–407.

Campbell, L.A., J.G. Hallett, and M.A. O'Connell. 1996. Conservation of bats in managed forests: use of roosts by *Lasionycteris noctivagans*. Journal of Mammalogy 77:976–984.

Carter, T.C. 1998. The foraging ecology of three species of bats at the Savannah River site, South Carolina. M.Sc. Thesis, University of Georgia, Athens, GA. 74pp.

Carter, T.C., and J.M Menzel. 2007. Behavior and day-roosting ecology of North American foliage-roosting bats. Pp. 61–81 *in* M.J. Lacki, J.P. Hayes, and A. Kurta, eds. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, MD.

Chatwin, T.A. 2004. Keen's Long-eared Myotis, *Myotis keenii*. Accounts and measures for managing Identified Wildlife – Accounts V. 2004. B.C. Ministry of Water, Land and Air Protection, Victoria, BC. 7pp. [http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Mammals/m_keensmyotis.pdf]

Chruszcz, B. 1999.Foraging and thermoregulatory behaviour of the Long-eared Bat (*Myotis evotis*) roosting in natural habitat. M.Sc. Thesis, University of Calgary, Calgary, AB.

Clark, B.S., D.M. Leslie, Jr., and T.S. Carter. 1993. Foraging activity of adult female Ozark Big-eared Bats (*Plecotus townsendii ingens*) in summer. Journal of Mammalogy 74:422–427.

Cryan, P.M. 2003. Seasonal distribution of migratory tree bats (*Lasiurus* and *Lasionycteris*) in North America. Journal of Mammalogy 84:579-593.

Cryan, P.M., M.A. Bogan, R.O. Rye, G.P. Landis, and C.L. Kester. 2004. Stable hydrogen isotope analysis of bat hair as evidence for seasonal molt and long-distance migration. USGS Staff—Published Research. U.S. Geological Survey. University of Nebraska, Lincoln NE. Paper 120. [http://digitalcommons.unl.edu/usgsstaffpub/120]

Cryan, P.M., M.A. Bogan, and G.M. Yanega. 2001. Roosting habits of four bat species in the Black Hills of South Dakota. Acta Chiropterologica 3:43–52.

Davis, R. 1966. Homing performance and homing ability in bats. Ecological Monographs 36:201–237.

Davis, W.H., and H.B. Hitchcock. 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. Journal of Mammalogy 46:296–313.

Dobkin, D.S., R.D. Gettinger, and M.G. Gerdes. 1995. Springtime movements, roost use and foraging activity of Townsend's Big-eared Bat (*Plecotus townsendii*) in central Oregon. Great Basin Naturalist 55:315–322.

Duchamp, J.E., D.W. Sparks, and J.O. Whitaker, Jr. 2004. Foraging habitat selection by bats at an urban-rural interface: comparison between a successful and a less successful species. Canadian Journal of Zoology 82:1157–1164.

Elmore, L.W., D.A. Miller, and F.J. Vilella. 2004. Foraging area size and habitat use by Red Bats (*Lasiurus borealis*) in an intensively managed pine landscape in Mississippi. American Midland Naturalist 153:405–417.

Evelyn, M.J., D.A. Stiles, and R.A. Young. 2004. Conservation of bats in suburban landscapes: roost selection by *Myotis yumanensis* in a residential area in California. Biological Conservation.115:463–473.

Falxa, G. 2005. Do large colonies create long commutes? Examining Myotis bat foraging distances and duration. Poster Cascadia Research Collective, Olympic Peninsula, WA. [http://cascadiaresearch.org/bats/pubs/2005_Myotis_Commute_Poster_Olympia.pdf]

Fellers, G.M., and E.D. Pierson. 2002. Habitat use and foraging behavior of Townsend's Big-eared Bat (*Corynorhinus townsendii*) in coastal California. Journal of Mammalogy 83:167–177.

Fenton, M.B., and R.M.R. Barclay 1980.*Myotis lucifugus*. Mammalian Species 142:1–8.

Fenton, M.B., C.G. van Zyll de Jong, G.P. Bell, D.B. Campbell, and M. Laplante. 1980. Distribution, parturition dates, and feeding of bats in south-central British Columbia. Canadian Field-Naturalist 94:416–420.

Fleming, T.H., and P. Eby. 2003. Ecology of bat migration. Pp. 156–208 *in* T.H. Kunz and M.B. Fenton, eds. Bat ecology. University of Chicago Press, Chicago, IL. 779pp.

Gruver, J.C., and D.A. Keinath. 2006. Townsend's Big-eared Bat (*Corynorhinus townsendii*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region.

Henderson, L.E., and H.G. Broders. 2008. Movements and resource selection of the Northern Long-eared Myotis (*Myotis septentrionalis*) in a forest-agriculture landscape. Journal of Mammalogy 89:952–963. [http://www.smu.ca/faculty/hughbroders/documents/jmamm08pei.pdf]

Henry, M., D.W. Thomas, R. Vaudry, and M. Carrier. 2002. Foraging distances and home range of pregnant and lactating Little Brown Bats (*Myotis lucifugus*). Journal of Mammalogy 83:767–774.

Hickey, M.B., and M.B. Fenton. 1990. Foraging by Red Bats (*Lasiurus borealis*): Do intraspecific chases mean territoriality? Canadian Journal of Zoology 68:2477–2482.

Hitchcock, H.B. 1965. Twenty-three years of bat banding in Ontario and Quebec. Canadian Field Naturalist 79: 4–14.

Hirt, S.J. 2008. Analysis of stable isotopes of hydrogen to determine migrational source of Silver-haired Bats (*Lasionycteris noctivagans*) in Alabama. M.Sc. Thesis, Auburn University, Auburn, AL. 25pp.

Holloway, G.L., and R.M.R. Barclay. 2001. *Myotis ciliolabrum*. Mammalian Species 670:1–5.

Humphrey, S.R., and T.H. Kunz. 1976. Ecology of a Pleistocene relict, the Western Big-eared Bat (*Plecotus townsendii*) in the southern Great Plains. Journal of Mammalogy 57:470–494.

Hutchinson, J.T., and M.J. Lacki. 1999. Foraging behavior and habitat use of Red Bats in mixed mesophytic forests of the Cumberland Plateau, Kentucky. Pp. 171–177 *in* J.W. Stringer and D.L. Loftis, eds. Proceedings of the 12th Central Hardwood Forest Conference. USDA Forest Service, Asheville, NC. General Technical Report SRS-24.

Hutchinson, J.T., and M.J. Lacki. 2000. Roosting behavior and foraging activity of a female Red Bat with non-volant young. Bat Research News 41(2):36–37.

Jain, A.A., R.R. Koford, A.W. Hancock, and G.G. Zenner. 2011. Bat mortality and activity at a northern Iowa wind resource area. American Midland Naturalist 165:185–200.

Johnson, J.S., M.J. Lacki, and M.D. Baker. 2007. Foraging ecology of Long-legged Myotis (*Myotis volans*) in north-central Idaho. Journal of Mammalogy 88:1261–1270.

Johnston, D.S., and M.B. Fenton. 2001. Individual and population-level variability in diets of Pallid Bats (*Antrozous pallidus*). Journal of Mammalogy 82:362–373.

Keinath, D.A. 2003. Species assessment for Fringed Myotis (*Myotis thysanodes*) in Wyoming. Prepared for the U.S. Department of the Interior, Bureau of Land Management, Wyoming State Office, Cheyenne, WY. 71pp. [http://www.uwyo.edu/wyndd/_files/docs/reports/speciesassessments/fringedmyotis-dec2003.pdf]

Keinath, D.A. 2004. The Fringed Myotis (*Myotis thysanodes*): a technical conservation assessment. Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project. 100pp.

Kunz, T.H., E.B. Arnett, W.P. Erickson, A.R. Hoar, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle. 2007. Ecological impacts of wind energy on bats: questions, research needs, and hypotheses. Frontiers in Ecology and the Environment 5:315–324.

Kunz, T.H., and R.A. Martin. 1982. *Plecotus townsendii*. Mammalian Species 175:1–6.

Kunz, T.H., and J.D. Reichard. 2010. Status review of the Little Brown Myotis (*Myotis lucifugus*) and determination that immediate listing under the *Endangered Species Act* is scientifically and legally warranted. In collaboration with Friends of Blackwater Canyon, Wildlife Advocacy Project, Bat Conservation International, Center for Biological Diversity, Meyer Glitzenstein and Crystal. 30pp. [http://www.bu.edu/cecb/files/2010/12/Final-Status-Review.pdf]

Lacki, M.J., S.K. Amelon, and M.D. Baker. 2007. Foraging ecology of bats in forests. Pp. 83–127 *in* M.J. Lacki, J.P. Hayes, and A. Kurta, eds. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, MD.

Lacki, M.J., and M.D. Baker. 2007. Day roosts of female Fringed Myotis (*Myotis thysanodes*) in xeric forests of the Pacific Northwest. Journal of Mammalogy 88:967–973.[http://www2.ca.uky.edu/Forestry/mamm.pdf]

Lausen, C.L. 2007. Roosting ecology and landscape genetics of prairie bats. Ph.D. Thesis, University of Calgary, Calgary, AB. 271pp.

Leput, D.W. 2004. Eastern Red Bat (*Lasiurus borealis*) and Eastern pipistrelle (*Pipistrellus subflavus*) maternal roost selection: implications for forest management. M.Sc. Thesis, Clemson University, SC. 172pp.

Mather, M., T.A. Chatwin, and M. Davis. 2000. Bat usage of Weymer Creek cave system on Vancouver Island. Unpublished report to the Habitat Conservation Trust Fund, Nanaimo, BC.

McGuire, L.P., C.G. Guglielmo, S.A. MacKenzie, and P.D. Taylor. 2012. Migratory stopover in the long-distance migrant Silver-haired Bat, *Lasionycteris noctivagans*. Journal of Animal Ecology 81:377–385.

Menzel, J.M., M.A. Menzel, J.C. Kilgo, W.M. Ford, J.W. Edwards, and G.F. McCracken. 2005. Effect of habitat and foraging height on bat activity in the coastal plain of South Carolina. Journal of Wildlife Management 69:235–245.

Nagorsen, D.W., and R.M. Brigham. 1993. Bats of British Columbia. Royal British Columbia Museum Handbook.Vol.1. The Mammals of British Columbia. UBC Press, Vancouver, BC. 164pp.

Nagorsen, D.W., A.A. Bryant, D. Kerridge, G. Roberts, A. Roberts, and M.J. Sarell. 1993. Winter bat records for British Columbia. Northwest Naturalist 74(3):61–66.

Ormsbee, P.C. 1996. Characteristics, use, and distribution of day roosts selected by female *Myotis volans* (Long-legged Myotis) in forested habitat of the central Oregon Cascades. Pp. 124–131 *in* R.M.R. Barclay and R.M. Brigham, eds. Bats and forest symposium. Proceedings of First International Bat-Forest Interactions Symposium, Victoria, BC, 19–21 October 1995. B.C. Ministry of Forests, Research Branch, Victoria, BC. Working Paper 23/1996. 292pp.

O'Shea, T.J., and T.A. Vaughan. 1977. Nocturnal and seasonal activities of the Pallid Bat, *Antrozous pallidus*. Journal of Mammalogy 58:269–284.

Owen, S.F., M.A. Menzel, W.M. Ford, B.R. Chapman, K.V. Miller, J.W. Edwards, and P.B. Wood. 2003. Home-range size and habitat used by the Northern Myotis (*Myotis septentrionalis*). American Midland Naturalist 150:352–359.

Perry, R.W. 2011. Fidelity of bats to forest sites revealed from mist-netting recaptures. Journal of Fish and Wildlife Management 2:112–116.

Pierson, E.D. 1998. Tall trees, deep holes, and scarred landscapes: conservation biology of North American bats. Pp. 309–325 *in* T.H. Kunz and P.A. Racey, eds. Bat biology and conservation. Smithsonian Institution Press, Washington, DC.

Pierson, E.D., M.C. Wackenhut, J.S. Altenbach, P. Bradley, P. Call, D.L. Genter, C.E. Harris, B.L. Keller, B. Lengus, L. Lewis, B. Luce, K.W. Navo, J.M. Perkins, S. Smith, and L. Welch. 1999. Species conservation assessment and strategy for Townsend's Big-eared Bat (*Corynorhinus townsendii townsendii* and *Corynorhinus townsendii pallescens*). Idaho Department of Fish and Game, Idaho Conservation Effort, Boise, ID. 68pp.

Rainey, W.E. 2005. *Myotis lucifugus*, Little Brown Bat. Species Account for the Western Bat Working Group. 2pp. [http://www.wbwg.org/]

Rambaldini, D.A. 2006. Behavioural ecology of the Pallid Bat (Chiroptera: *Antrozous pallidus*) in British Columbia. Prepared for Osoyoos (Nk'Mip) Indian Band, Oliver, BC. B.C. Ministry of Environment, Penticton, BC and Canadian Wildlife Service, Delta, BC. 82pp.

Rancourt, S.J., M.L. Rule, and M.A. O'Connell. 2005. Maternity roost site selection by Long-eared Myotis, *Myotis evotis*. Journal of Mammalogy 86:77–84. [http://www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_2/Inland_Northwest_Complex/Turnbull/Documents/Rancourtetal%20JM.pdf]

Rodhouse, T.J., and R.G. Wright. 2010. Study of bat roosts in John Day Fossil Beds National Monument 2003. Upper Columbia Basin Network. U.S. Department of the Interior, National Park Service, Natural Resources Program Center, Fort Collins, CO. Natural Resource Technical Report NPS/UCBN/NRTR-2010/305. 41pp.

Sarell, M. 2004. Spotted Bat, *Euderma maculatum*. Accounts and measures for managing Identified Wildlife – Accounts V. 2004. B.C. Ministry of Water, Land and Air Protection, Victoria, BC. 7pp. [http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Mammals/m_spottedbat.pdf]

Saugey, D.A., R.L. Vaughn, B.G. Crump, and G.A. Heidt. 1998. Notes on the natural history of *Lasiurus borealis* in Arkansas. Journal of the Arkansas Academy of Science 52:92–98. [http://dante.ddns.uark.edu/aas/issues/1998v52/v52a14.pdf]

Schowalter, D.B., and A. Allen. 1981. Late summer activity of Small-footed, Long-eared, and Big Brown Bats in Dinosaur Park, Alberta. Blue Jay 39:50–53.

Smyth, M.S. 2000. A maternity colony of Townsend's Big-eared Bats, *Corynorhinus townsendii*. M.Sc. Thesis, University of British Columbia, Vancouver, BC. 102pp. [https://circle.ubc.ca/bitstream/id/25662/ubc_2000-0271.pdf]

Shump, K.A., Jr., and A.U. Shump. 1982. *Lasiurus cinereus*. Mammalian Species 185:1–5.

Stantec Consulting Ltd. 2010. Wolfe Island Ecopower Centre: post-construction follow-up plan, bird and bat resources. Monitoring Report No. 2, July–December 2009. Prepared for TransAlta Corporation's wholly owned subsidiary, Canadian Renewable Energy Corporation. 100pp. [http://www.batsandwind.org/pdf/Wolfe%20Island-bird-monitoring-report-2h2009.pdf]

Towanda, T., and G. Falxa. 2007. Emergence and foraging patterns of *Myotis lucifugus* and *M. yumanensis* bats in the southern Puget Sound region. Poster for Evergreen State College, by Cascadia Research. [http://cascadiaresearch.org/bats/pubs/2007_TESC_Bat_Poster.pdf]

van Zyll de Jong, C.G. 1979. Distribution and systematic relationships of Long-eared Myotis in Western Canada. Canadian Journal of Zoology 57:987–994.

van Zyll de Jong, C.G., and D.E. Nagorsen. 1994. A review of the distribution and taxonomy of *Myotis keenii* and *Myotis evotis* in British Columbia and the adjacent United States. Canadian Journal of Zoology 72:1069–1078.

Vonhof, M.J., and R.M.R. Barclay. 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology 74:1797–1805. [http://www.nrcresearchpress.com/doi/pdf/10.1139/z96-200]

Wai-Ping, V., and M.B. Fenton. 1989. Ecology of the Spotted Bat (*Euderma maculatum*) roosting and foraging behaviour. Journal of Mammalogy 70:617–622.

Waldien, D.L., and J.P. Hayes. 2001. Activity areas of female Long-eared Myotis in coniferous forests in western Oregon. Northwest Science 75:307–314. [https://research.wsulibs.wsu.edu:8443/xmlui/bitstream/handle/2376/942/v75%20p307%20Waldien%20and%20Hayes.PDF?sequence=1]

Walters, B.L., C.M. Ritzi, D.W. Sparks, and J.O. Whittaker, Jr. 2007. Foraging behavior of eastern Red Bats (*Lasiurus borealis*) at an urban-rural interface. American Midland Naturalist 157:365–373.

Whitford, J. 2009. Ripley wind power project post-construction monitoring report. Prepared for Suncor Energy Products Inc. Project No. 1037529.01. 277pp. [http://www.wind-watch.org/documents/ripley-wind-power-project-post-construction-monitoring-report/]

Wilkinson, L.C., and R.M.R. Barclay. 1997. Differences in the foraging behaviour of male and female Big Brown Bats (*Eptesicus fuscus*) during the reproductive period. Ecoscience 4:279–285.

Woodsworth, G.C. 1981. Spatial partitioning by two species of sympatric bats, *Myotis californicus* and *Myotis leibii*. M.Sc. Thesis, Carleton University, Ottawa, ON.

Woodsworth, G.C., G.P. Bell, and M.B. Fenton. 1981. Observations of the echolocation, feeding behaviour, and habitat use of *Euderma maculatum* (Chiroptera: Vespertilionidae) in southcentral British Columbia. Canadian Journal of Zoology 59:1099–1102.