BENEFICIAL MANAGEMENT PRACTICES FOR BATS

For the Milk River and the South Saskatchewan Watershed in Alberta

Report prepared for

Alberta Conservation Association

MULTISAR Project

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1 INTRODUCTION

There are at least nine species of bats in Alberta, and all but one (the Northern Myotis; *Myotis septentionalis*) frequently occur on the prairies (Table 1). Three of these species – Hoary Bat, Eastern Red Bat, and Silver-haired Bat – are long-distance migrants and are presumed to leave the province during the winter to find milder climates farther south. The remaining species are believed to be year-round residents, with most hibernating in the province during the winter, but may still undergo shorter distance migrations to reach suitable hibernacula. Although considerable advancements have been made over the last few decades to better understand the biology of bats, substantial knowledge gaps still exist, including basic information on distribution, habitat use, migration, and winter ecology.

Bats reproduce slowly relative to other mammals, with the majority of females giving birth to a single pup per year, and usually not until their second or third summer (Barclay and Harder 2003). The three migratory bats are the exception, often having litters of two pups per year. To compensate for their slow rate of reproduction, bats are capable of living exceptionally long lives. For example, Little Brown Myotis in Alberta can live up to at least 39 years, which is facilitated by a naturally low mortality rate (Barclay and Harder 2003, Hobson 2014). However, their slow reproductive rate results in bat populations being particularly sensitive to human caused mortality or other factors affecting survival and reproductive success.

Several prairie bat species are conservation concerns. Migratory bats appear to be particularly sensitive to mortality at some wind energy facilities, both in the province and elsewhere in North America (Arnett and Baerwald 2013). Although fewer year-round residents are killed at wind energy facilities, there is substantial concern about the potential introduction of white-nose syndrome, a fungal disease killing millions of hibernating bats in eastern North America (COSEWIC 2013). Two of the most common bat species in Alberta, the Little Brown Myotis and Northern Myotis, have been listed as Endangered under the Species at Risk Act because of concerns about the continuing spread of white-nose syndrome. Some species, in particular the Western Small-footed Myotis, have narrow distributions along a few prairie rivers and may be sensitive to localized disturbances (Lausen and Schowalter 2008). The cumulative effects of multiple stresses, including wind turbines, disease, habitat loss, and human disturbance is of particular concern given their already low reproductive rates (Boyles *et al.* 2011, Francl *et al.* 2012, Arnett and Baerwald 2013).

Many prairie bats roost in buildings and forage over human modified landscapes, most of which are located on private land. Farmyards frequently have old buildings attractive to bats, especially if located near good foraging habitat such as wetlands or riparian zones. Bats provide substantial benefits as predators of insect pests, but their close association with people makes them particularly susceptible to disturbance and mortality from human activities (Brigham 1993). Voluntary participation of landowners and other members of the public is therefore an important component of conservation, stewardship, research, and monitoring programs benefiting bats (Environment Canada 2015).

Most bats in Alberta use treed habitats to some extent, either for roosting or foraging. However, the three long-distance migrants show a particularly strong dependence on trees for use as roosting sites. On the Alberta prairies, treed habitats are relatively common towards the foothills to the west, the parkland to the north, or the Cypress Hills to the east. However, across much of the open prairies in southern Alberta, treed habitats are primarily associated with riparian zones and bat activity is highly concentrated within these areas. Of particular importance for bats in this region are the riparian cottonwood forests, which for the purpose of bat habitat may hereafter refer to Balsam Poplar (*Populus balsamifera*), Plains Cottonwood (*Populus deltoides*), or Narrowleaf Cottonwood (*Populus angustifolia*). Similarly, Trembling Aspen (*Populus tremuloides*) provides important roosting habitat in many regions of the province (Kalcounis and Brigham 1998, Olson and Barclay 2013). Riparian zones provide important sources of drinking water, abundant insect prey, and shelter from the wind. The numerous rock crevices or erosion cavities in riparian zones also provide important roosting and hibernation habitat used by several prairie bat species, especially those that are year-round residents. Degradation or destruction of riparian zones is a concern for bat conservation in Alberta, and has important implications for the design of grazing systems and other beneficial management practices.

2 GENERAL BAT ECOLOGY

Bats undergo a series of life history events throughout the year that strongly affect habitat use. This includes migration, rearing offspring, mating, and for most bats, hibernation. Despite inherent differences in the over-winter strategy between migratory and year-round resident bats, the characteristics and timing of life history events is similar – although not identical – among the nine bat species in Alberta. Several studies have reported the timing of life history events; however, considerable year-to-year and regional variation in timing may occur depending on ambient conditions and the quality of local resources (Koehler and Barclay 2000, Lausen and Barclay 2006*a*).

Bats begin migrating into Alberta, or emerging from hibernation, around April, and shortly thereafter females move to their summer breeding range (Schowalter and Gunson 1979, Schowalter *et al.* 1979, Lausen 2007). Pups are typically born from about June to late-July and are weaned about 4-6 weeks later (Kunz 1971, Kurta *et al.* 1989, Barclay 1993, Lausen 2007). Dispersal from summer breeding ranges begins shortly after pups are able to forage on their own, at which time they undertake short or long-distance migrations to their winter range. Mating occurs during the fall and/or winter, but pregnancy is delayed until the following spring. Bats either leave Alberta, or hibernate in the province, from about September to April, although there may be considerable variation in arrival and departure times among individual bats (Lausen 2007).

2.1 General Habitat Requirements

All bats require open water for drinking, and access to high quality foraging and roosting habitat for survival and successful reproduction (Kurta 2000). Bats adapted to fast long-distance flight (e.g., Hoary Bats, Big Brown Bats) are likely better able to use more dispersed resources, but habitat suitability is likely greatest when these resources can be accessed without the need for energetically expensive long-distance movements. Resources isolated from other required resources are likely to be underutilized by bats. For example, foraging habitat generally has higher bat activity when located near suitable roosts (Furlonger *et al.* 1987). There is little evidence that bats defend discrete territories as observed with many songbirds, and multiple individuals and/or bat species frequently co-occur in the same area. However, some bats do establish discrete roosting areas, either individually or as a colony, which may have little overlap with neighboring groups (Willis and Brigham 2004, Lausen 2007, Olson and Barclay 2013). Kinship appears to strongly influence habitat use for some species (e.g., Western Small-footed Myotis) (Lausen 2007), while others (e.g., Big Brown Bats) are frequently found in mixed groups of related and unrelated individuals (Metheny *et al.* 2008).

Trees, rock crevices, and buildings provide important roosting habitat for bats throughout the province. However, in treeless prairie landscapes, rock crevices and erosion holes are especially important as roost sites for a variety of bat species (Lausen 2007, Nixon *et al.* 2009). These structures are generally restricted to riparian zones, and are the result of erosional processes occurring over long-time periods, making them slow to reestablish once lost. Foraging is concentrated in areas where flying insects are abundant, often coinciding with wet areas, treed habitats, and areas sheltered from the wind. Similar to roosting habitat, high quality foraging habitat is also most abundant in riparian zones, and bat activity and diversity is especially high in these areas (Holloway and Barclay 2000). Bats use a diversity of roosting structures and foraging habitats throughout the year, and consume insect prey that also benefit from healthy diverse landscapes (Kurta 2000, van Klink *et al.* 2015). Therefore, effective management needs to focus on ensuring diverse landscapes with a wide diversity of foraging and roosting habitat, as well as access to drinking water (Kurta 2000). Typical maternity roosts and hibernacula known or suspected to be used by Alberta bats is shown in Table 1, and described in more detail in the subsequent sections.

Table 1. Roosting and hibernation habitat used by bats in the Milk River and South Saskatchewan River Basin.

Species	Typical maternity roosting habitat[1]	Hibernation habitat[2]
Long-distance migratory bats (leave Alberta during the winter; may still hibernate on their wintering grounds)		
Hoary Bat (*Lasiurus cinereus*)	▪ Solitary roosts hidden among the foliage of tall trees	▪ Unknown; over-winter habitat occurs in warmer climates
Eastern Red Bat (*Lasiurus borealis*)	▪ Solitary roosts hidden among the foliage of tall trees ▪ May roost under leaf litter on cold days (behaviour unconfirmed in Alberta)	▪ Under leaf litter in the southeastern United States
Silver-haired Bat (*Lasionycteris noctivagans*)	▪ Tree cavities (e.g., cottonwood, aspen)	▪ Caves, mines, and tree cavities in warmer climates
Year-round resident bats (assumed to hibernate in Alberta; may undergo short-distance migrations to reach hibernacula)		
Big Brown Bat (*Eptesicus fuscus*)	▪ Buildings and bat houses ▪ Tree cavities (e.g., aspen) ▪ Rock/mudstone crevices; usually well above level ground (e.g., cracks along vertical faces, erosion holes, rock overhangs, boulders)	▪ Deep rock crevices or mudstone erosion holes in prairie river valleys ▪ Buildings ▪ Caves
Little Brown Myotis (*Myotis lucifugus*)	▪ Buildings, bridges, and bat houses ▪ Tree cavities (e.g., cottonwood, aspen) ▪ Rock crevices (e.g., small caves, crevices along vertical slopes)	▪ Caves (other structures likely)
Long-eared Myotis (*Myotis evotis*)	▪ Rock/mudstone crevices; often near the ground (e.g., boulders, rock piles, cliffs, erosion holes and channels) ▪ Tree cavities; stumps; downed logs ▪ Buildings	▪ Deep rock crevices or mudstone erosion holes in river valleys (probable)
Long-legged Myotis (*Myotis volans*)	▪ Buildings, bridges, and bat houses ▪ Rock crevices ▪ Tree cavities (probable)	▪ Caves (other structures likely)
Western Small-footed Myotis (*Myotis ciliolabrum*)	▪ Rock/mudstone crevices in riparian badlands (e.g., erosion holes and channels, crevices along cliffs)	▪ Deep rock crevices or mudstone erosion holes in river valleys (probable)

Notes: (1) Roosting habitat is based on reports from Alberta, or where necessary, reports outside Alberta representing similar habitat. Atypical roosts excluded. Most bats are opportunistic, and additional roosting structures may be used that are not reported here. Tree cavities may refer to a variety of structural defects in living or dead trees, such as knotholes, cracks, breakages, woodpecker cavities, and sloughing bark. See in-text for references.
(2) Hibernation habitat is mostly unknown. The few confirmed or likely hibernacula for Alberta bats are shown. Additional structures may have been reported for other jurisdictions that are not shown here.

2.2 Roosting Behaviour

2.2.1 Day and Night Roosts

Three types of roosts may be used by bats in Alberta: day roosts, night roosts, and hibernacula (Kunz 1982*a*). Day roosts are sheltered locations where bats spend the daylight hours. Night roosts are used during temporary pauses in foraging activity during the night, such as to rest or digest food (Kunz 1982*a*). Day roosts may also be used as night roosts, especially when mothers are nursing pups (Barclay 1982). Differences in roost use often occur between sex and reproductive classes, and likely relate to changes in the use of torpor (a reduction in body temperature that saves energy but delays growth and fetal development), as well as the need to provide warm stable temperatures for vulnerable pups (Lausen and Barclay 2003). Therefore, within the same species, markedly different roosting habitats may be used depending on whether individuals are males, non-reproductive females, pregnant females, or lactating females (Lausen and Barclay 2003, Broders and Forbes 2004).

With the exception of winter cave and mine hibernacula surveys, most studies of roosting behaviour focus on day roosts used during the summer months when bats are on their breeding grounds, and most often target reproductive females. As a result, the majority of roosting information presented in this report is based on maternity roosts (i.e., roosts used by pregnant or lactating females). However, reproductive bats have heightened energy demands and need to provide conditions suitable for developing offspring, making the availability of suitable maternity roosts a particularly important management priority. Some species – such as the Little Brown Myotis and Big Brown Bat – also form large maternity colonies consisting of reproductive females and their pups. Large colonies are only likely to occur in large roosting structures, further limiting the range of structure that these bats are able to use (Olson and Barclay 2013).

Much less information is available for night roosts. Although night roosts are used for shorter durations, they may still serve an important function for bats – such as to conserve energy, allow digestion of food, facilitate information transfer, avoid predation, and possibly, as sites for mating (Ormsbee *et al.* 2007). Some species of bats (e.g., Long-legged Myotis, Little Brown Myotis) have been observed using communal night roosts separate from their day roosts, and often at a few consistent locations, such as bridges and buildings (Barclay 1982, Perlmeter 1995, Ormsbee 1996). Because night roosts are used in conjunction with foraging bouts, the availability of night roosts could influence the use of potential foraging habitats (Perlmeter 1995). Night roosts used by bats on the prairies may be the same roost used during the day, but also includes additional structures such as small caves (Holloway 1998).

Most bats show high fidelity to specific roosting areas during the summer breeding season, but begin to disperse during the late summer and fall. Once bats leave their summer home ranges, additional roosts will be needed as stop-over sites during migration (Cryan and Veilleux 2007). This includes both long-distance migrants, as well as year-round residents that may still move considerable distances between summer breeding grounds and hibernacula. A wide range of roosting structures are used during the spring or fall while bats are dispersing and may be unfamiliar with available roosting options – not surprisingly, this is the period when many people observe errant bats (Pybus 1994). Yet more structures may be used during certain times of the year as swarming sites (Schowalter 1980). This primarily includes fall swarming sites, which often occurs around caves (which may also be used for hibernation) and may coincide with mating. Aggregations of bats may also occur during spring dispersal from hibernacula, resulting in brief concentrations of bat activity at select roosts (Schowalter *et al.* 1979).

Bats have many behaviours that result in unique patterns of habitat use distinct from birds. Bats do not build nests or otherwise modify structures used to raise offspring. Instead already existing structures are used, such as buildings, trees, rock crevices, and erosion holes. Female bats exclusively rear offspring. With the exception of lasiurine bats (i.e., Hoary and Eastern Red Bats), most reproductive female bats exhibit at least some degree of sociality during parts of the breeding season. Depending on species and location, roosting groups can range anywhere from two up to over a thousand individuals. Because bats do not modify roost structures, these groups may be important for elevating roost temperature and providing conditions suitable for raising offspring. However, large groups require spacious roosting structures, which may be uncommon in some areas (Olson and Barclay 2013).

An important behaviour of bats is the ability to carry offspring among roosts. This allows bats to use multiple different roosts throughout the breeding season. Bats occupying permanent structures, such as buildings, often reuse the same structure for long-periods (Lewis 1995). However, natural roosting colonies occupying ephemeral roosts in trees and rock crevices may move as frequently as every night, and do not necessarily roost with the same individuals (or number of individuals) after successive movements (Lausen and Barclay 2002, Willis and Brigham 2004, Olson and Barclay 2013). The reasons for this behaviour are unknown, but in some species it appears to allow bats to maintain familiarity with a much greater number of individuals than would be able to fit in a single roost (Willis and Brigham 2004). Although individual roost fidelity may be low, many species occupying natural roosts appear to show a high level of fidelity to roost areas, often selecting roosts among a particular patch of trees or rock crevices (Lewis 1995, Lausen 2007, Olson 2011). This behaviour strongly suggests that conservation efforts and land management in areas with natural roosting habitat need to consider the availability of a diversity of potential roosts within the broader landscape, rather than focusing primarily on individual roosting structures.

2.2.2 Hibernacula and Winter Ecology

Hibernacula are winter roosts used for the purpose of hibernation, which occurs sometime between September 1st to April 30th. The winter ecology of most bat species in Alberta is poorly understood. Most reports in the province come from a few isolated hibernacula, representing an insubstantial portion of the overall population (Olson *et al.* 2011). Known hibernacula include a small number of caves containing Little Brown Myotis, Long-legged Myotis, and/or Northern Myotis (Schowalter 1980, Olson *et al.* 2011), as well as a few building, cave, and rock crevice hibernacula used by Big Brown Bats (Schowalter and Gunson 1979, Lausen and Barclay 2006*b*). Big Brown Bats are the only species known to regularly hibernate in buildings (Schowalter and Gunson 1979).

Bats that hibernate during the winter accumulate substantial fat deposits during the fall, and rely on these energy stores for overwinter survival (Kunz *et al.* 1998). Although bats may emerge from hibernation during the winter to mate or drink water, foraging cannot occur until insects begin flying in the spring (Lausen and Barclay 2006*b*). Energy conservation is critical to overwinter survival and is achieved through the use of prolonged torpor, characterized by reductions in body temperature and reduced metabolic rate (Boyles and Brack 2009). Ideal hibernacula are well protected from predators and have stable, cool temperatures that remain above freezing throughout the winter (Neubaum *et al.* 2006, Tuttle and Kennedy 2011). These sites differ from roosts used by reproductive females during the breeding season, which typically prefer warm roosts that facilitate rapid juvenile growth (Solick and Barclay 2006*a*).

Cave hibernacula are often sites where swarming behaviour (typically of Myotis spp.) is observed during the fall, prior to hibernation. Swarming is associated with periods of high flight activity by multiple bats, typically near the entrance to a hibernacula (Fenton and Barclay 1980). For year-round resident bats, fall swarming and hibernation appear to be important times for mating. Intermixing of bats that spend the summer in different regions appears common during the fall and winter (Fenton and Barclay 1980), possibly being important for gene flow within a population. The majority of bats captured hibernating or swarming near known cave hibernacula in Alberta appear to be male (Schowalter 1980), which adds further uncertainty to the winter habitat requirements of Alberta bats. With the exception of Big Brown Bats, the winter behaviour of bats that don't hibernate in caves is mostly unknown or inferred from cave and mine-roosting populations. However, observations of sperm production and storage imply mating occurs during the fall and/or winter for all prairie bat species (Barclay 1993).

Bats are particularly sensitive to disturbance that occurs during hibernation. Disturbance may cause bats to emerge from hibernation, and expend energy reserves that are needed for overwinter survival and reproduction the following spring (Boyles and Brack 2009). Frequent or prolonged disturbances may lead to higher mortality and/or or depleted fat stores needed for spring migration and reproduction (Boyles and Brack 2009, Boyles and Willis 2010).

2.3 Foraging Behaviour

All bats in Canada forage on arthropods, primarily insects and spiders. Dietary composition is dependent on the availability of different prey species in their habitat, which will vary among geographic regions, habitats, seasons, and years (Clare *et al.* 2011, Valdez and O'Shea 2014). Bats will shift their foraging strategy to take advantage of differences in the timing of activity or emergence of different prey species (Clare *et al.* 2011, 2014). Similarly, bats will take advantage of outbreaks of palatable insects, and shift to alternative food sources when their main prey base is depleted (Wilson and Barclay 2006, Valdez and O'Shea 2014). Prey availability has a strong influence on habitat selection, with bats more likely to occupy areas where preferred prey species are abundant (Holloway and Barclay 2001). Variation in prey populations can cause shifts in the locations where bats concentrate their foraging activity. Geographic and temporal changes in insect availability mean that studies involving dietary analysis may not necessarily be applicable to all time periods or throughout the range where a species occurs. However, features that attract insects (e.g., wetlands, riparian corridors, and treed areas) are known to be consistently important foraging habitats for bats (Holloway and Barclay 2000).

In addition to prey availability, morphology and echolocation properties dictate the prey species that bats are able to capture (Aldridge and Rautenbach 1987, Kalcounis and Brigham 1995). Larger bodied bats with stronger bites (e.g., Big Brown Bats and Hoary Bats) can select a greater range of prey sizes, including large beetles and moths, while small bats are restricted to eating smaller prey (Aldridge and Rautenbach 1987). Larger bats with high wing loading are restricted to foraging in more open areas, whereas smaller bats, with broad wings, are better able to forage within high-clutter habitats, such as the forest understory (Norberg and Rayner 1987). Because bats rely on echolocation to capture prey, differences in the properties of their echolocation calls can have a strong influence on the range of prey they are best able to target (Barclay 1986). Bats with higher frequency echolocation calls with broad frequency sweeps (e.g., most Myotis spp.) are better able to detect both small and large-bodied insects than bats with low frequency narrowband echolocation calls (e.g., Hoary Bats). Generally, larger and/or faster bats have lower frequency echolocation calls because these calls attenuate less over distance, and facilitate higher speed foraging in open areas.

Many bats are predators of agricultural and forestry pests. These include a variety of moth species – such as Gypsy Moths (*Lymantria dispar*), tent caterpillars (*Malacosoma* sp.), and Army Cutworms (*Euxoa auxiliaris)* – as well as various species of leafhoppers (Cicadellidae), stink bugs (Pentatomidae), rootworms (*Diabrotica spp*.), scarab beetles (Scarabaeidae), and flies (Muscidae) (Whitaker 1995, Holloway 1998, Clare *et al.* 2009, Valdez and O'Shea 2014). In addition, bats consume large numbers of various biting insects, such as mosquitoes and black flies (Barclay 1985, Holloway 1998, Clare *et al.* 2014*b*). The value of bats for controlling agricultural insect pests has been estimated to be more than $3.7 billion dollars / year in the United States (Boyles *et al.* 2011). Therefore, land management practices beneficial for bats may also provide significant benefits to agricultural operations and contribute to sustainable land management objectives (Heim *et al.* 2015).

2.4 Predators

There are no predators in Alberta that specialize on bats, but several species of birds and mammals are opportunistic predators (Lima and O'Keefe 2013). Because of their slow reproductive rate, mortality from predation must be low for populations to be maintained (Barclay and Harder 2003). Bats have a variety of anti-predator behaviours that have a strong influence on habitat use (Lima and O'Keefe 2013). The nocturnal behaviour of bats is in large part a requirement to avoid predation, especially by diurnal birds. For similar reasons, variations in the light level within or among nights can affect the timing and location of habitat use. Roost selection is strongly influenced by predation, and all species in Alberta show strong selection for locations that are inaccessible, well protected, and/or hidden from predators. Well protected roosts, such as narrow crevices and buildings, may be important resources for reducing predation risk (Lausen and Barclay 2006*a*).

Most reports of predation of bats are of opportunistic observations, making the relative importance of different predators hard to evaluate. However, several reports have been made of diurnal birds (especially corvids) opportunistically locating and killing bats. Important diurnal predators include Black-Billed Magpies (*Pica hudsonia*) (Boxall 1982, Hochachka and Scharf 1986), Blue Jays (*Cyanocitta cristata*; Hoffmeister and Downes 1964), American Crows (*Corvus brachyrhynchos*) (Hernández *et al.* 2007), and Loggerhead Shrike (*Lanius ludovicianus*) (Sarkozi and Brooks 2003). The risk of predation by diurnal wildlife likely increases for bats using more exposed roosts (e.g., Eastern Red Bats), sick or injured bats, bats forced from their roosts because of disturbance, or dispersing adults and juveniles unable to find suitable roosts.

Owls are a likely, but rarely observed, predator of bats. Several owls found in Alberta are known to periodically prey on bats, including Great Horned Owls (Jung *et al.* 2011), Long-eared Owls (Bosakowski and Smith 1992), and Northern Saw-Whet Owls (Sealy 1999). However, most large owls likely lack sufficient maneuverability to capture bats in great numbers (Janos and Root 2014). House cats, which are common around buildings where bats roost, are a major predator of bats in agricultural areas (Fenton and Barclay 1980, Ancillotto *et al.* 2013).

3 HOARY BAT

3.1 Background

The Hoary Bat (*Lasiurus cinereus*) is the largest bat in Canada and has the greatest range of any bat in the Americas (Shump and Shump 1982*a*). They are found throughout Alberta, especially in areas where trees are available, such as along rivers and farmyards (Barclay 1993). Their reliance on trees makes them sensitive to the loss or degradation of treed habitats, especially on the prairies where trees may be scarce. Like the Eastern Red Bat and the Silver-haired Bat, they undergo long-distance migrations out of the province to reach suitable winter habitat. Although the majority of Hoary Bats in Alberta likely breed in the parkland and boreal forest regions of the province, many (possibly most) will pass through southern Alberta during migration (Holloway 1998, Baerwald *et al.* 2014). Therefore, management of prairie habitats has potential to have disproportionate effects on Hoary Bat populations throughout western Canada.

The proliferation of wind energy facilities in southern Alberta has become a major source of mortality for the species (Baerwald and Barclay 2011, Arnett and Baerwald 2013). This is especially true of turbines situated near major movement corridors, such as the foothills and river valleys (Baerwald and Barclay 2009). Bats appear to be attracted to wind turbines, and may be especially prone to fatalities due to their susceptibility to barotrauma as well as direct strikes with turbine blades (Baerwald *et al.* 2008, Arnett and Baerwald 2013). Across North America, hundreds of thousands of Hoary Bats have likely been killed by wind turbines over approximately the last decade (Arnett and Baerwald 2013). Furthermore, annual fatalities are likely increasing as a result of the rapid expansion of wind energy production. The absence of long-term monitoring data for bats prevent detailed assessment of population changes; however, available data suggests a decrease in migratory tree-bat populations in North America (Arnett and Baerwald 2013).

3.2 Ecology

Fatalities at wind energy facilities in southern Alberta indicate that fall migration begins by the middle of July, peaks around early to mid-August, and then subsides by the first week of September (Baerwald and Barclay 2011). Adult males move through southern Alberta earlier during the fall than females and juveniles. Most male Hoary Bats begin storing sperm by late August, and mating is assumed to occur from late summer through winter, with pregnancy delayed until spring (Cryan *et al.* 2012, 2014). Spring migration in Alberta is poorly understood, but spring records suggests that at least some Hoary Bats are in Alberta by early April (Lausen 2007). Females arrive approximately one month before males, and may disperse farther into Canada (Findley and Jones 1964, Cryan 2003, Cryan *et al.* 2014). Females arrive during the spring already pregnant, and give birth around mid-June to early July (Barclay 1993, Koehler and Barclay 2000). Females have one litter per year, which typically consists of two pups, but may range from 1 to 4 pups (Shump and Shump 1982*a*). Bats begin flying around 30 days old, and weaning occurs about 3 weeks later (Koehler and Barclay 2000). Both male and female juvenile Hoary Bats typically reach sexual maturity during their first autumn (Cryan *et al.* 2012).

3.2.1 Diet

Lepidoptera (specifically moths) are typically the primary food source of Hoary Bats in southern Alberta and elsewhere. However, like other bats, they are opportunistic foragers and will take advantage of regional and temporal variation in insect availability (Barclay 1985, Holloway 1998, Reimer *et al.* 2010, Perlik *et al.* 2012, Valdez and Cryan 2013). Barclay (1985) found that Hoary Bats were not necessarily moth specialists, but instead fed opportunistically on large bodied insects, which included large moths, Coleoptera (beetles), and Odonata (dragonflies). However, if given the opportunity, large soft-bodied insects, such as moths, appear more likely to be selected over beetles and other hard-bodied insects (Perlik *et al.* 2012). Larger-sized moths appear to be preferred, especially moths of the family Noctuidae (owlet moths) (Hickey *et al.* 1996, Valdez and Cryan 2009). This contrasts with the smaller, but ecologically similar, Eastern

Red Bat which more often selects smaller moths, such as those from the family Tortricidae (leafroller moths) (Hickey *et al.* 1996).

Despite the apparent selection of Lepidoptera, other insect orders may comprise an important, or dominant, component of their diet, especially in certain regions or during certain times of the year (Barclay 1985). Approximately half the diet of a small sample of adult Hoary Bats found dead at a wind energy facility in southern Alberta consisted of Lepidoptera; however, most of the remainder consisted of Hemiptera (specifically Corixidae [water boatmen]) (Reimer *et al.* 2010). Approximately half the diet of migratory juvenile Hoary Bats also consisted of Lepidoptera, but the remainder of the diet was more evenly split among Coleoptera, Hemiptera (water boatmen), and Diptera (true flies). Hoary Bats in Manitoba often fed extensively on Lepidoptera, but Coleoptera and Odonata were also substantial dietary components and dominated diets during certain times of the year (Barclay 1985, Rolseth *et al.* 1994). In Manitoba, Diptera (specifically Chironomids) were the dominate prey consumed by juveniles during the first week after they began flying (Rolseth *et al.* 1994). Variation in prey selection was also observed within nights. Bats in Manitoba were found to consume most Odonata towards the end of their nightly foraging activity (Barclay 1985). A variety of prey species is apparently beneficial by reducing variability in insect availability throughout the night and across seasons.

3.3 Habitat Requirements

3.3.1 General

Hoary Bats occupy a variety of habitats from northern Canada to South America (Shump and Shump 1982*a*). They are fast, open country flyers capable of traversing long distances in search of required food, water and shelter. However, trees are required for roosting, which is likely to concentrate their activity on the prairies to regions where suitable roost trees are available, such as along riparian corridors or closer to the Foothills, Rocky Mountain, or Parkland Natural Regions. They undergo long-distance migration during the spring and fall, and therefore require suitable stopover habitat along migration routes (Cryan and Veilleux 2007). Suitable habitat is also required while on their winter range, but very little is known about habitat use at this time.

3.3.2 Foraging Habitat

The body size, wing morphology, and echolocation properties of the Hoary Bat makes it one of the best adapted bat species in Alberta for open-space foraging, but one of the least adapted to navigating cluttered environments (Barclay 1985, 1986). The properties of their echolocation calls allow detection of large bodied flying insects over relatively long distances, accommodating their fast flight speeds along linear foraging paths (Barclay 1986).

Foraging may occur over a variety of landscapes, but will be concentrated in areas where large flying insects are abundant and accessible. These areas include near the canopy of trees (Kalcounis *et al.* 1999), near forest edges (Furlonger *et al.* 1987), along rivers and waterbodies (Barclay 1985, Holloway and Barclay 2000), along ridges (Barclay 1985), and near artificial lighting (Barclay 1985, Furlonger *et al.* 1987, Hickey *et al.* 1996). Foraging around yard and streetlights is common, likely because these attract moths. Sites sheltered from the wind, such as the leeward side of ridges or along forest edges, are more likely to be used by foraging bats (Barclay 1985, Furlonger *et al.* 1987). On prairie landscapes, riparian cottonwood stands appear to be especially important due to the close proximity of high quality foraging and roosting habitat as well as water for drinking (Holloway and Barclay 2000).

3.3.3 Roosting Habitat

Like the Eastern Red Bat, Hoary Bats roost alone, or with their pups, typically high up in the open foliage of trees (Willis and Brigham 2005, Klug *et al.* 2012). This strategy gives them greater flexibility in roosting sites compared to species that must locate protected roost cavities. Non-foliage roosts are uncommonly used; however, they have been documented roosting in shrubs, bridges, and the sides of buildings (Shump and Shump 1982*a*:1982, Hendricks *et al.* 2005, Andrusiak 2008).

Hoary Bats require trees for roosting, which are uncommon in many areas of the prairies. Although the relative suitability of treed areas has not been examined, riparian corridors, hills/cliffs, shelterbelts, urban areas, and farmyards often have trees and may be used as roost sites by this species. Preference for the edges of forest clearings for roost sites has been reported (Constantine 1966), but the general applicability of this pattern has not been demonstrated. In forested areas, Hoary Bat activity is higher in stands with large live trees and an open canopy (Jung *et al.* 1999), which may be the result of roost availability. Within prairie landscapes, cottonwood forests along riparian corridors offers abundant roosting and foraging habitat, and may be critical roosting habitat for Hoary Bats and other tree-roosting species (Brigham 1993, Holloway and Barclay 2000).

3.3.4 Maternity Roosts

Hoary Bats roost alone, or with their pups, hidden among the foliage of tall trees (Shump and Shump 1982*a*). Individuals typically roost by hanging or clinging to small diameter branches, twigs, petioles, leaves/needles, and pine cones (Perry and Thill 2007). These locations are typically inaccessible to most mammalian predators, and have overhanging foliage that reduces the risk of detection by aerial predators (Willis and Brigham 2005). Roosts suitable for hoary bats are likely more common than crevices used by other tree-bats; however, several studies demonstrate a high degree of selectively for particular roost properties. Roosts in Canada are generally in locations that are sheltered from the wind and have a southern exposure, allowing passive heating by the sun (Willis and Brigham 2005, Klug *et al.* 2012). Selected trees are likely to be as tall, or taller, than nearby trees, and have a lower density of trees leading out from the roost location. A report of a Hoary Bat with pups using a bridge as a day roost suggests that they may be able to use structures other than trees as maternity roosts, but this behavior appears uncommon (Hendricks *et al.* 2005).

There are an inadequate number of roost selection studies specific to Alberta ecosystems to make broad descriptions of roosting habitat and roost tree selection by Hoary Bats in the province. However, Hoary Bats in the Cypress Hills, Saskatchewan, nearly exclusively selected mature White Spruce (*Picea glauca*), with the only exception being a single Trembling Aspen (*Populus tremuloides*) roost (Willis and Brigham 2005). However, spruce trees were typically the tallest trees in the study area, making it unclear whether they are selecting for roost-tree species or just roost height. Hoary Bats in other studies made extensive use of deciduous trees, albeit not of tree species that commonly occur in Alberta (Constantine 1966, Perry and Thill 2007, Klug *et al.* 2012).

3.3.5 Migration and Winter Habitat

Very little is known regarding the winter ecology of Hoary Bats. Their winter distribution includes warmer climates in the southern United States and coastal regions, where subfreezing temperatures are uncommon (Cryan and Veilleux 2007). Hibernation below leaf litter during cold periods, similar to that observed for the Eastern Red Bat, is possible but remains undocumented (Cryan and Veilleux 2007).

Hoary Bats are commonly reported during fall migration at wind energy facilities in southern Alberta. Observed patterns of fatalities and activity at wind energy facilities suggest that prairie rivers and the foothills along the eastern slopes of the Rocky Mountains may be used as migration corridors through southern Alberta (Baerwald and Barclay 2009). Stable isotope analysis of dead migrating bats collected in this region suggests that many of the Hoary Bats migrating through southern Alberta may have originated closer to the aspen parkland-like region of Alberta and/or adjacent prairie provinces (Baerwald *et al.* 2014).

3.3.6 Area Requirements

Like other bats, reproductive female Hoary Bats require a summer home range with sufficient access to open water for drinking, as well as suitable roosting and foraging habitat (Kurta 2000). Area requirements will depend on the spatial configuration and quality of these resources (Amelon *et al.* 2014); however, habitat suitability will go down as the distance between these resources increases. As fast open-country foragers, they are capable of long-distance flights, which allows them to span large distances in search of required resources (Perry and Thill 2007).

In Manitoba, Hoary Bats were observed to forage up to 20 km from their roost, with the average maximum foraging distance approximately 6.3 km for females nursing young (Barclay 1989). Hoary Bats may use the same tree for most of the breeding season, and show high inter-year roost fidelity, suggesting they do not require a large roosting area (Willis and Brigham 2005, Perry and Thill 2007, Klug *et al.* 2012). For example, Perry and Thill (2007) reported that the two reproductive bats in their study remained in their roost tree for over 23 to 26 days. Detailed studies on their home range size in Alberta, or elsewhere, have not been published.

4 EASTERN RED BAT

4.1 Background

The Eastern Red Bat (*Lasiurus borealis*) was once considered vagrant in Alberta. However, an increase in the number of surveys over the last few decades, primarily as part of regulatory requirements for oil sands and wind energy projects, has provided evidence that the species regularly occurs in the province (Lausen and Player 2014). Occurrence data spans much of Alberta, from southern Alberta to the oil sands region of northern Alberta, and as far west as Kananaskis (Lausen and Player 2014, Barclay pers. comm.). The species is widely distributed in southern Alberta, but activity is likely to be concentrated near areas where treed habitat is available for roosting, such as along prairie rivers and in the Cypress Hills (Willis and Brigham 2003, Alberta Environment and Parks 2016). Because the species requires trees for roosting, they are likely sensitive to the loss or degradation of treed areas, especially is southern areas were trees are often scarce (Barclay 1993). Long term monitoring data is not currently sufficient to provide reliable population trajectories for the province; however, available data suggests a reduction in Eastern Red Bats across North America over the last few decades (Arnett and Baerwald 2013, Vonhof and Russell 2015).

Eastern Red Bats across North America appear to represent a single large panmictic (i.e., genetically intermixed) population, and there is no evidence to support distinct migratory pathways or unique regional populations (Vonhof and Russell 2015). High gene flow among the North American population is likely the result of interbreeding during migration and overwintering when bats appear to concentrate in common winter habitat in southeastern North America (Cryan 2003).

All reported captures of this species in the province have been of males and non-reproductive females, making it uncertain whether the species actually breeds in Alberta (Lausen and Player 2014). A female caught during the fall in the Saskatchewan side of the Cypress Hills had evidently bred during the summer, but could have been passing through during migration (Willis and Brigham 2003). Sex ratios of captured or killed Eastern Red Bats in southern Alberta are also biased towards males, further suggesting the majority of individuals in the region are not actively breeding. However, few records exist of either sex in Alberta, making it uncertain whether available specimens are representative of the population as a whole. More even sex ratios have been observed in northern Alberta (Lausen and Player 2014); however, it is not known whether these individuals pass through southern Alberta during migration.

Fatalities at wind energy facilities in southern Alberta have been reported, but at far fewer numbers than for Silver-haired Bats or Hoary Bats (Baerwald and Barclay 2011). Across North America, Eastern Red Bats are likely the third most often killed bat species at wind energy facilities; however, the vast majority of these occur outside of Alberta in more eastern portions of their range (Arnett and Baerwald 2013). Fatalities at wind energy facilities over the last couple decades has likely exceeded one hundred thousand individuals in North America, and may worsen as new projects are developed (Arnett and Baerwald 2013). Vonhof and Russell (2015) used molecular techniques to estimate an effective population size of 591,000 across North America, suggesting current levels of mortality may represent a substantial portion of the overall population.

4.2 Ecology

The migratory behavior of Eastern Red Bats in Alberta is poorly understood as a result of few observations of the species in the province. However, timing appears similar to the Hoary Bat, with fall migration beginning by late July, peaking in August, and then subsiding by the end of September (Cryan 2003). Lausen (2007) did not detect Eastern Red Bats along the Red Deer River valley after the end of September, but had several detections during August and September. Males begin to store sperm by August (Cryan *et al.* 2012), and mating likely occurs before or during migration, or while they are on their winter range (Vonhof and Russell 2015). Bats return during the spring and are on their breeding grounds by June; however, the exact timing is poorly understood due to few spring observations (Cryan 2003). Lausen (2007) detected Eastern Red Bats along the Red Deer River beginning the first half of May. Breeding by Eastern Red Bats has not been confirmed in Alberta (Lausen and Player 2014); however, like the Hoary Bat, pregnancy is delayed until spring, with females in the eastern portions of their range giving birth around mid-June, and possibly into early July (Shump and Shump 1982*b*). Like other migratory bats, females typically give birth to more than one pup, and may start rearing pups as early as their second year (Cryan *et al.* 2012). There is only one litter per year, which averages approximately 2.3 pups per litter, and may be as high as 5 pups (Shump and Shump 1982*b*). The period of lactation last about 5 to 6 weeks, ending after young begin to fly and are able to forage on their own (Kunz 1971). Males may reach sexual maturity and begin storing sperm by their first autumn (Cryan *et al.* 2012).

4.2.1 Diet

There are no dietary studies specific to Alberta populations of Eastern Red Bats. Lepidoptera (moths) are typically reported to be major dietary components in studies across North America, suggesting they specialize on moths (Hickey *et al.* 1996, Carter *et al.* 2004, Whitaker 2004, Clare *et al.* 2009, Thomas *et al.* 2012). Nonetheless, they are opportunistic predators and will consume insects from a variety of orders. Clare *et al.* (2009) found that most prey consumed by Eastern Red Bats were Lepidoptera (specifically moths), with much lower proportions of Coleoptera (beetles), Diptera (flies), Ephemeroptera (mayflies), and Hymenoptera (bees and ants). Of the moths consumed, Noctuidae (owlet moths) were the majority of the diet, followed by much lower amounts of Pyralidae (snout moths), Tortricidae (leafroller moths), and Geometridae (geometer moths). Prey includes several pests of forest and farmland, such as tent caterpillars (*Malacosoma* spp.), cutworm moths (various species), and coneworms (*Dioryctria spp.*).

Hickey *et al.* (1996) found that when foraging with Hoary Bats, Eastern Red Bats tended to select smaller moth species, such as leafroller moths (Torticidae) while Hoary Bats selected larger moth species, such as owlet moths (Noctuidae). In South Carolina, Lepidoptera dominated the diet during late summer, while Coleoptera and Hemiptera (true bugs) were the most commonly consumed insect family earlier in the season (Carter *et al.* 2004). Variation in the diet appears to follow seasonal variation in insect availability.

4.3 Habitat Requirements

4.3.1 General

All bats require suitable foraging and roosting habitat and access to drinking water (Kurta 2000). Although Eastern Red Bats are capable of long distance flights between roosting and foraging grounds, habitats where these resources are in close proximity, such as riparian areas, are likely to be of greater value (Holloway and Barclay 2000, Menzel *et al.* 2005, Amelon *et al.* 2014). Habitat may change seasonally as bats move to and from their summer breeding habitat to their overwintering habitat (Cryan and Veilleux 2007). However, like the Hoary Bat, they show a high degree of reliance on trees for roost sites throughout the year, including during the breeding, migration, and winter period. Roosting (or hibernation) may also occur below leaf litter, particularly during the winter, which is a behaviour not commonly documented for other bat species (Moorman *et al.* 1999, Mager and Nelson 2001).

4.3.2 Foraging Habitat

Eastern Red Bats are generalist foragers and may occupy many different habitats and use a diverse range of foraging behaviors at different times or among different geographic areas (Hutchinson and Lacki 1999, Menzel *et al.* 2005). They are capable of navigating semi-cluttered environments, but also of fast, open air flight (Shump and Shump 1982*b*, Menzel *et al.* 2002). Foraging may occur in both forested and non-forested habitats, in both open and semi-cluttered habitats, both above and below forest canopies, and in both early or later stage forests (Hutchinson and Lacki 1999, Menzel *et al.* 2005, Loeb and Keefe 2006).

Eastern Red Bats are primarily a woodland species. But at a finer scale, non-forested openings and forest edges appear to be important habitat elements (Hutchinson and Lacki 1999, Walters *et al.* 2007, Amelon *et al.* 2014). Although edges are often used for foraging, excessive fragmentation or clearing may reduce habitat quality (Hutchinson and Lacki 1999, Amelon *et al.* 2014). Some foraging occurs over pastures and other agricultural lands, especially near woodland edges, but heavily disturbed habitats such as dense urban developments, transportation corridors, and mines are generally avoided (Hutchinson and Lacki 1999, Walters *et al.* 2007). Foraging may occur around human developments, especially where lights attract moths that are eaten by Eastern Red Bats (Furlonger *et al.* 1987, Hickey *et al.* 1996).

No information currently exists on foraging habitat used by Eastern Red Bats in Alberta. However, in more eastern locations of North America where the species is more common, high activity has been observed near riparian habitats and associated drainages, wetlands, open water, and ridges (Barclay 1984, Hart *et al.* 1993, Hutchinson and Lacki 1999, Menzel *et al.* 2005, Amelon *et al.* 2014). Although they did not examine Eastern Red Bats, Holloway and Barclay (2000) found that bat activity in southeastern Alberta was concentrated along rivers and small springs, which coincided with high levels of insect biomass. Riparian cottonwood stands, in particular, have among the highest bat activity on the prairies, and it is likely the best available roosting and foraging habitat for Eastern Red Bats.

4.3.3 Roosting Habitat

Eastern Red Bats typically roost among the foliage of trees, and occasionally shrubs, throughout most of the year (Hutchinson and Lacki 2000, Mager and Nelson 2001, Elmore *et al.* 2004, Limpert *et al.* 2007, Perry *et al.* 2007). Most studies of roosting behaviour are of diurnal roosts used during the breeding season, and generally from hardwood or pine forests from eastern North America. The behaviour of western populations is mostly unknown, but on the open prairies, they presumably rely on treed riparian corridors to find suitable roost trees.

Use of structures other than trees during the summer months appears rare. However, Mager and Nelson (2001) reported roosts under shake shingles on a house, as well as a roost hidden among dense grass, suggesting they are capable of using structures other than trees. Roosting is also known to occur under leaf litter during cold periods, especially during the winter (Mager and Nelson 2001, Mormann and Robbins 2007). This behaviour facilitates prolonged periods of torpor (reduction in body temperature), which may last several days (i.e., short periods of hibernation). Use of leaf-litter roosts appears important for conserving energy during periods when it is too cold to support flying insect prey. Mormann and Robbins (2007) found that the majority of Eastern Red Bats in Missouri used leaf litter roosts during winter periods when the ambient temperature was less than 10ºC. In warmer portions of their range, leaf litter roosts are used much less often during the summer compared to the winter (Mager and Nelson 2001, Mormann and Robbins 2007). Because Eastern Red Bats likely do not overwinter in Alberta, it is unclear how commonly leaf litter roosts are used in the province. However, at least some use of leaf litter roosts appears likely, especially during cold spring conditions.

Males and non-reproductive females appear to be more flexible in their roost use, roosting lower and occasionally using small trees and shrubs (Constantine 1966, Perry *et al.* 2007). Roosting may occur in forests from a wide age range (O’Keefe *et al.* 2009), but commonly occurs in mature or old forests where tall canopy or overstory trees are selected as roosts (Hutchinson and Lacki 2000, Limpert *et al.* 2007, Perry *et al.* 2007). In open or fragmented habitats, such as urban or agricultural areas, roosting may occur in smaller patches of old trees in otherwise open habitats (Mager and Nelson 2001).

Several studies have found Eastern Red Bats commonly using – or preferentially selecting – sites near anthropogenic and natural edges, including roads, trails, open water, and wetlands (Constantine 1966, Perry *et al.* 2007, O’Keefe *et al.* 2009). However, Hutchinson and Lacki

(2000) found that bats in their study area never roosted within 50 m from the edge of otherwise contiguous forest. This behaviour was suggested to be a strategy to avoid predators, such as jays and other corvids, which were known to concentrate their activity along forest edges. Few studies have examined tree bats on the prairies, so comprehensive information on predation risk is not available. Nonetheless, small tree patches in agricultural areas tend to concentrate activity by Black-billed Magpies and other corvids known to be predators of bats (Boxall 1982, Saab 1999). As a result, there is uncertainty whether small residual tree patches on the prairies would represent suitable habitat for bats, especially for a small species using relatively exposed foliage roosts. Larger treed patches, such as occurs along rivers, likely offers higher quality roosting habitat and may be associated with a reduced risk of predation by corvids and other predators (Saab 1999).

4.3.4 Maternity Roosts

Like the Hoary Bat, Eastern Red Bats roost alone, or with their pups, in roosts hidden among the foliage of tall trees (Shump and Shump 1982*b*). Individuals hang or cling from branches, twigs, petioles, or leaves, often in clumps of thick foliage near the end of branches (Shump and Shump 1982*b*, Mager and Nelson 2001). Locations are selected that have overhead foliage for cover, and that have open flight space below the roost (Mager and Nelson 2001). Roosting appears to occur near the edge of the crown and at sufficient heights to prevent access by mammalian predators (i.e., > 5 m).

Foliage roosting may allow younger and more abundant trees to be used as roosts than with cavity-roosting species. However, as is observed by the Hoary Bats, there may still be strong selection for specific roosting locations (Hutchinson and Lacki 2001, Willis and Brigham 2005). In particular, Eastern Red Bats appear to select locations that have lower temperature variability and reduced exposure to temperature extremes (Hutchinson and Lacki 2001). Although not examined for Eastern Red Bats in northern climates, they may have a similar preference for southern exposures and protection from wind that was reported for Hoary Bats in this region (Willis and Brigham 2005, Klug *et al.* 2012).

Roost selection studies are typically from southeastern North America, and may not be applicable to western Canada where much different tree species dominate the landscape. However, most studies report that Eastern Red Bats are most likely to select living large-diameter deciduous trees (Mager and Nelson 2001, Elmore *et al.* 2004, Limpert *et al.* 2007). Roost trees are typically canopy height, or overstory, large-leaved species with broad protective crowns (Hutchinson and Lacki 2000, Mager and Nelson 2001, Perry *et al.* 2007). In some parts of their range, they may also use conifer species, including Loblolly Pine (*Pinus taeda*) and Shortleaf Pine (*Pinus echinata*), but these are generally avoided when suitable deciduous species are present (Elmore *et al.* 2004, Perry *et al.* 2007). Although dominant or codominant trees appear to be preferred, the size of trees used will vary between regions. For example, in some parts of their range, average tree diameters range from 26 to 28 cm (Elmore *et al.* 2004, Perry *et* *al.* 2007, O'Keefe *et al.* 2009), while in other areas, average roost tree diameter exceeds 40 cm (Hutchinson and Lacki 2000, Limpert *et al.* 2007). Reproductive females appear more likely to select large diameter trees than males (Elmore *et al.* 2004) and may roost at a greater height than non-reproductive bats (Constantine 1966, Perry *et al.* 2007). Males, in particular, have been observed to use sapling trees as roosts, which is rarely reported for reproductive females (Perry *et al.* 2007).

4.3.5 Migration and Winter Habitat

Eastern Red Bats overwinter in the southeastern United States, and then disperse into northwestern regions during the warmer months (Cryan 2003). Their summer range includes regions as far north as the Northwest Territories (Lausen *et al.* 2014). Migration routes have not been determined, but a small number of predominately males are regularly detected during fall migration in southern Alberta (Baerwald and Barclay 2011, Alberta Environment and Parks 2016). It is unclear whether Eastern Red Bats occupying the boreal forest migrate through southern Alberta. Assuming their destination is the southeastern United States, individuals living in the north could potentially bypass treeless prairie habitats during fall migration by heading southeast across the boreal plains. They could then fly south through the eastern forests to reach their overwinter habitat in the southeastern United States (and then the reverse in the spring). Although they may be active during warmer days of the winter (Whitaker *et al.* 1997), they are known to hibernate beneath leaf litter during cold periods (Moorman *et al.* 1999, Mormann and Robbins 2007).

4.3.6 Area Requirements

Eastern Red Bats are well adapted to fast flight in open spaces, and can navigate large areas to find foraging and roosting habitat and sources of drinking water. There is no evidence that Eastern Red Bats raise offspring in Alberta, especially in the south where mostly males have been observed (Lausen and Player 2014); therefore, it is unclear whether area requirements for this species in the province reflects those of reproductive females, or the presumably lower resource and area requirements of transient males and non-reproductive females. Regardless, no habitat studies have been completed for Eastern Red Bat populations in Alberta or neighboring provinces, so area requirements in Alberta are largely unknown for any demographic. Nonetheless, home range size estimates of Eastern Red Bats have been relatively well studied for the southeastern United States.

Like the Hoary Bat, Eastern Red Bats may have high fidelity to very small roosting areas during the summer months (Elmore *et al.* 2005, Walters *et al.* 2007). Individuals of a variety of sex and age classes had average roosting areas < 1 ha from June to August in Mississippi (Elmore *et al.* 2005). This was despite frequent roost switching among available trees within these areas. Likewise, in Kentucky, roosts used by individual males or females typically occurred within a 40 m^2 area from May through August (Hutchinson and Lacki 2000).

Several studies have examined foraging area use in Eastern Red Bats. Reuse of foraging areas across multiple nights appears to be common during the summer (Hutchinson and Lacki 1999, Walters *et al.* 2007, Amelon *et al.* 2014). Individuals use a variety of foraging strategies, including long-distance linear flights along edges (Amelon *et al.* 2014). As a result, foraging home range size estimates may vary considerably among individuals depending on the foraging strategy used. Additional variability among studies may result from differences in habitat quality and availability, the spatial configuration of required resources, and research methodology (e.g., estimation technique for home ranges). Lactating Eastern Red Bats in Missouri had a maximum foraging distance of 20 km from their day roosts, and a mean foraging area (excluding outer 1% of observations) of 1,357 ha (range 202 to 3,728 ha) (Amelon *et al.* 2014). In Mississippi, Eastern Red Bats traveled a maximum distance of 1.2 km (range 0.19 km to 3.28 km) from day roosts to their foraging area, and had a mean foraging area (excluding outer 5% of observations) of 94 ha (Elmore *et al.* 2005). In an urban-rural transition zone in Indiana, Eastern Red Bats had a maximum foraging distance that ranged from 0.42 km to 1.76 km, and an average home range size (excluding outer 5% of observations) of 68 ha (range 30 ha to 143 ha) (Walters *et al.* 2007). In Kentucky, the maximum distances that bats foraged from their roosts ranged from 1.2 to 5.5 km and 1.4 to 7.4 km for females and males, respectively, with an average across all bats of 2.7 km (Hutchinson and Lacki 1999). In the Kentucky study, the average foraging areas for females and males were 295 ha (range 113 to 850 ha) and 450 ha (range 134 to 925 ha), respectively. Males are typically reported to have larger foraging areas than females, but most studies do not have sufficient sample sizes to find statistically significant results (Hutchinson and Lacki 1999, Elmore *et al.* 2005).

5 SILVER-HAIRED BAT

5.1 Background

Silver-haired Bats (*Lasionycteris noctivagans*) are one of three bat species in Alberta that are long-distance migrants and assumed to leave the province during the winter. Their range spans across most regions of North America, from the northern boreal forest (Wilson *et al.* 2014) to Mexico (Kunz 1982*b*). Roosting occurs primarily under bark and in the cavities of trees, making them reliant on habitats where large decaying trees are available (Barclay 1993). Riparian forest is likely especially important for providing roosts in otherwise treeless prairie landscapes (Barclay 1993). However, Silver-haired Bats are generally uncommon in grassland environments except during migration (Holloway 1998), and the majority of bats observed during migration in Alberta appear to breed in the boreal forest to the north (Baerwald *et al.* 2014).

High fatalities at wind energy facilities are an important conservation concern for Silver-haired Bats in Alberta, and this is expected to intensify as new facilities come into operation (Government of Alberta 2012, Arnett and Baerwald 2013). They are the second most commonly reported bat species found dead at wind turbines in Alberta and across North America (Baerwald and Barclay 2011, Arnett and Baerwald 2013). Over approximately the last decade, cumulative fatalities at wind energy facilities have likely exceeded one hundred thousand individuals across North America (Arnett and Baerwald 2013). Their reliance on trees for roosting also makes them sensitive to activities that remove or degrade treed habitats, especially in grassland environments where trees are most likely to be limited (Brigham 1993, Holloway and Barclay 2000).

5.2 Ecology

Fall migration for Silver-haired Bats in southern Alberta begins around mid to late July, peaks around late August, and then subsides around mid-September (Baerwald and Barclay 2011). Both male and female Silver-haired Bats appear to migrate through southern Alberta at similar times during the fall. Migration routes and winter destinations are poorly understood, but presumably includes warmer regions towards the south, or westward towards the coast (Izor 1979, Cryan 2003). Spring migration is less well studied than fall migration, but bats begin appearing in Alberta by the end of March or early April (Schowalter *et al.* 1978, Olson pers. obs.). Female biased sex ratios have been documented in the province (Schowalter *et al.* 1978). However, a strong sex bias in fatalities at a wind energy facility in southwestern Alberta was not evident during fall migration (Baerwald and Barclay 2011). Few studies have reported the timing of reproduction in southern Alberta, but pups are likely born sometime during June or July (Barclay 1993). Litter size has rarely been observed, but females likely give birth to one or, more commonly, two pups per year (Kunz 1982*b*). Litters of three pups have also been observed in Canada, but it is unclear whether they can successfully raise this many offspring (Baerwald, E. pers. comm.). Lactation lasts approximately 5 to 6 weeks, although juveniles begin flying and foraging on their own by about 4 to 5 weeks after birth (Kunz 1971). Males may be ready to mate by late August, but mating appears more likely to occur sometime after September and possibly into winter (Cryan *et al.* 2012). Both males and females reach sexual maturity during their first autumn.

5.2.1 Diet

Silver-haired Bats have a broad diet and will opportunistically consume a variety of flying insects that they encounter during their aerial foraging bouts (Barclay 1985). Lepidoptera (moths), Diptera (true flies), and Hemiptera (true bugs) appear to be major dietary component for Silver-haired Bats in many areas (Whitaker Jr *et al.* 1977, 1981, Barclay 1985, Carter *et al.* 2003, Lacki *et al.* 2007, Ober and Hayes 2008, Reimer *et al.* 2010). However, most studies report a wide dietary breadth composed of several insect orders, with various studies across their range reporting substantial components of Coleoptera (beetles), Hymenoptera (bees and ants), Isoptera (termites), Neuroptera (net-winged insects), and Trichoptera (caddisflies) (Whitaker 1972, Whitaker Jr *et al.* 1977, 1981, Carter *et al.* 2003, Lacki *et al.* 2007, Ober and Hayes 2008, Reimer *et al.* 2010). Their diet will change throughout the year, depending on the availability and seasonal timing of different prey items. For example, Silver-haired Bats at Delta Marsh in Manitoba foraged heavily on Dipterans throughout the breeding season, but the types of dipterans changed markedly as the year progressed (Barclay 1985). Chironomids dominated diets in June, but were nearly absent from diets in August-September. Muscoid flies were found during all periods, but especially during the early spring. Mosquitoes were an appreciable component of the diet from August to September, but a relatively small component earlier in the season.

Few studies have examined the diet of Silver-haired Bats in western Canada, but presumably they show the same regional and inter-annual variably seen elsewhere. One study examined the diets of juvenile and adult Silver-haired Bats found dead at a wind energy facility in southern Alberta, and found over two thirds of the diet to be dominated by Lepidoptera and Diptera, with most of the remainder consisting of Hemiptera (including Homoptera) and Coleoptera (Reimer *et al.* 2010).

5.3 Habitat Requirements

5.3.1 General

All bats require suitable foraging and roosting habitat and access to drinking water (Kurta 2000). Silver-haired Bats are capable of long-distance flights over treeless landscapes to reach these resources, but rely on trees for roosting, especially old decaying trees with protected cavities. As a result, the distribution of trees, especially of larger patches of forested habitat, has a large influence on habitat use by Silver-haired Bats. As one of few regions of the prairies where trees regularly grow, riparian zones are important habitat for Silver-haired Bats (Holloway and Barclay 2000). Riparian zones provide important breeding habitat for a variety of species, including the Silver-haired Bat. However, for migratory species, riparian zones may be especially important as stopover habitat and migration corridors through otherwise inhospitable terrain. Extensive tree cover is also found along the foothills to the west, as well as the parkland natural region to the north, and the Cypress Hills to the east, which may allow a greater range of habitats to be used in these regions.

5.3.2 Foraging Habitat

Silver-haired Bats forage in both young and old forest, as well as forest openings, but are often concentrated along forest edges (Crampton and Barclay 1995, Hogberg *et al.* 2002, Jantzen and Fenton 2013). Optimal foraging habitat may occur along forest edges because they provide habitat for insects and shelter from the wind (Verboom and Huitema 1997). The lee side of ridges, especially forested ridges, may similarly provide shelter from the wind, and have been observed to be important foraging habitat for Silver-haired Bats (Barclay 1985). Sheltered areas not only reduce the energetic demands of flight, but may also have higher concentrations of insects, thereby increasing foraging success by bats (Verboom and Huitema 1997).

Foraging habitat by Silver-haired Bats in southern Alberta is difficult to assess, in part because the species has similar echolocation calls to Big Brown Bats, so cannot be reliably differentiated using acoustic monitoring. However, river valleys are known to be important foraging and roosting habitats for a variety of bats on the prairies, and the availability of large cottonwoods makes these attractive sites for Silver-haired Bats. Areas with steep topography, such as riparian cliffs and coulees, provide shelter from the wind, and are often used by foraging bats (Holloway and Barclay 2000). Riparian cottonwood stands have among the highest foraging activity by prairie bats, and would provide similar foraging habitat to what Silver-haired Bats use in other parts of their range.

5.3.3 Roosting Habitat

Silver haired bats appear to roost almost exclusively in trees during the breeding season. However, they may occasionally roost on buildings, especially during migration when they lack familiarity with suitable roosting locations (Schowalter 1979). In addition, observations of cave and rock-crevice hibernacula in British Columbia (Lausen 2015) suggests that the potential use of rock crevices during the breeding or migration period may require additional investigation.

Female Silver-haired Bats generally roost in small groups within concealed tree cavities or under bark (Crampton and Barclay 1998). These structures are generally only found in large diameter decaying trees and snags, particularly of deciduous species. Not surprisingly, most roosts occur in old forests where these trees are more likely to occur (Campbell *et al.* 1996, Crampton and Barclay 1998). Roosting habitat in the open prairie of southern Alberta is limited and likely does not support a large reproductive population (Schowalter *et al.* 1978). Away from the foothills and Cypress Hills, most roosts in southern Alberta are likely found in riparian woodlands, especially where large decaying cottonwood are present (Holloway and Barclay 2000).

5.3.4 Maternity Roosts

Maternity colonies are typically located in the cavities of large diameter trees, and often in old woodpecker cavities (Barclay and Kurta 2007). In western Canada, trees used by maternity colonies are often large-diameter Trembling Aspen and other species of the *Populus* genus, which have deep cavities resulting from cracks, breakage, scars, knot holes, or woodpecker cavities (Crampton and Barclay 1998, Vonhof and Gwilliam 2007). In the Cypress Hills, they roost in a variety of large diameter Balsam Poplar and Trembling Aspen (Bohn pers. comm.), which is similar to observations in northern Alberta (Crampton and Barclay 1998). Few other records have been published in southern Alberta. However, a maternity colony, estimated to have no more than 24 individuals, was found along the battle river in southwestern Alberta (Baerwald pers. comm.). The colony was roosting in a broken-over cottonwood snag, with the roost entrance no more than a couple meters above the ground. Likewise, cottonwood in arid regions of southern British Columbia are believed to be important roosting structures (Nagorsen and Brigham 1993). Deciduous species (especially *Populus* sp.) typically have decay characteristics that make them ideal as roost sites for colonial species. In particular, heart-rot infections at the site of breakages often results in large well protected inner chambers that are ideal for roosting (Parsons *et al.* 2003). In other parts of their range, especially regions where large-diameter deciduous species are uncommon, coniferous species are used as roost trees (Campbell *et al.*

1996, Mattson *et al.* 1996, Vonhof and Barclay 1996). Several studies report the frequent use of old woodpecker cavities by Silver-haired Bats (Parsons *et al.* 1986, Mattson *et al.* 1996, Vonhof and Barclay 1996). On the prairies, large diameter trees and snags are most likely to be found in riparian valleys, and most breeding on the open prairies is likely restricted to these areas (Barclay 1993, Holloway and Barclay 2000).

Several studies indicate that reproductive female Silver-haired Bats roost in small colonies during the summer months (Parsons *et al.* 1986, Mattson *et al.* 1996, Betts 1998, Crampton and Barclay 1998, Vonhof and Gwilliam 2007). For a study in northern Alberta, emergence counts averaged 9.1 individuals (maximum 24) (Crampton and Barclay 1998). In southern British Columbia, emergence counts averaged 11 individuals (range 1 to 35). In Oregon, emergence counts ranged from 5 to 16 (Betts 1998). Frequent roost switching is common, even among reproductive females with dependent young (Betts 1998, Crampton and Barclay 1998). Bats in northern Alberta used roosts an average of 2.7 days before switching to a new roost (Crampton and Barclay 1998), which is similar to the average of 2.9 days reported for a study in Oregon (Betts 1998).

5.3.5 Migration and Winter Habitat

Large migrations of Silver-haired Bats have been documented in southern Alberta (Schowalter *et al.* 1978, Baerwald and Barclay 2011), and most are assumed to leave the province during the winter to find warmer overwinter habitat. Stable isotope analysis of hair samples collected from dead bats suggests that many of the Silver-haired Bats passing through southern Alberta during fall migration may have spent the summer in the boreal forest, hundreds of kilometers to the north (Baerwald *et al.* 2014). The foothills along the eastern slopes of the Rocky Mountains appear to be used as a migration corridor for bats, with a potentially large catchment that could include large portions of the boreal forest (Baerwald and Barclay 2009, Baerwald *et al.* 2014). Prairie river valleys also appear to be used as migration corridors, and may help bats traverse otherwise treeless habitats (Lausen 2007, Baerwald and Barclay 2009, Government of Alberta 2013).

The ultimate destination of migrating bats in Alberta has not been identified, but presumably is somewhere with milder winter conditions. Silver-haired Bats are known to overwinter in the United States and southeastern British Columbia (Cryan 2003, Lausen 2015). In southeastern British Columbia, Silver-haired Bats have been documented hibernating in mines, rock crevices, trees and snag (Lausen 2015). A westward migration of silver-haired bats from Alberta into British Columbia is not supported by available evidence (Cryan 2003), but may warrant additional study. Hoary Bats, which also migrate in large numbers, appear to often make long-distance longitudinal movements towards warmer coastal regions (Cryan *et al.* 2014), but this has yet to be reported for Silver-haired Bats.

5.3.6 Area Requirements

Information on home range and foraging area estimates of reproductive Silver-haired Bats is lacking. However, some radio-telemetry studies report distances between capture locations and roosting locations. These distances can provide an indication of the minimum distance bats are travelling during a night to forage. In South Dakota, individuals moved an average of 2,060 m from their capture location to roosting sites (Mattson *et al.* 1996). In British Columbia, a few females of the same colony moved an average of 390 m between their capture location and roost site (Vonhof and Barclay 1996). In northeastern Washington, the average distance between capture and roost locations was 0.5 km (range 0.1 to 1.8 km) for adult females, 1.5 km (range 1.3 to 1.7 km) for juvenile females, 1.8 km (range 0.2 to 3.4 km) for adult males, and 1.3 km (range 0.1 to 2.5) for juvenile males (Campbell *et al.* 1996).

Several studies report frequent roost switching by reproductive females, with reported average distances between subsequent roosts typically ranging from about 183 m to 405 m (Mattson *et al.* 1996, Vonhof and Barclay 1996, Betts 1998, Crampton and Barclay 1998). In one study, individuals moved up to 1,100 m between subsequent roosts (Betts 1998). Silver-haired Bats likely need substantial areas of large-diameter decaying trees from which to select their roost. The minimum area of suitable trees required to support Silver-haired Bats in currently unknown, and would depend on the density and distribution of suitable roost cavities.

6 BIG BROWN BAT

6.1 Background

Big Brown Bats (*Eptesicus fuscus*) are among the most common species on the prairies (Pybus 1994). They resemble the Little Brown Myotis in appearance, but are much larger, averaging a little over twice their mass. Adults weigh between about 13 to 23 g, making them the second largest bat in Alberta (Lausen 2007). Their range extends across most of the Americas from northwest South America, north at least as far as the southern Northwest Territories (Kurta 1990, Wilson *et al.* 2014). They have a wide range in Alberta, but are absent or patchily distributed across large areas of the boreal forest (Pybus 1994).

Human structures are often used for roosting and hibernation, and is possibly their primary roosting habitat in some locations (Schowalter and Gunson 1979). The apparent abundance of Big Brown Bats on the prairies suggests that buildings may provide benefits that often outweigh potential risks. However, like the Little Brown Myotis, the close association of Big Brown Bats with people makes them susceptible to deliberate or accidental disturbance or mortality from human activities. They also appear to prefer older buildings, and it is unknown whether modern building designs are as likely to provide suitable roost conditions for the species (Schowalter and Gunson 1979).

Mortality at wind energy facilities is known to occur in southern Alberta and elsewhere across North America (Baerwald and Barclay 2011, Arnett and Baerwald 2013). However, Big Brown Bats typically represent a far smaller proportion of fatalities compared to migratory species. Fatalities of Big Brown Bats represent about 4% of fatalities across select wind energy sites in North America (Arnett and Baerwald 2013), and were fewer than 2% of fatalities during fall migration at a wind energy facility in southern Alberta (Baerwald and Barclay 2011). However, these fatalities may still be an important source of mortality for resident populations.

As a resident hibernating species, Big Brown Bats are susceptible to white-nose syndrome (WNS), and are among the species known to have been killed by this disease in eastern North America (Foley *et al.* 2011). However, susceptibility to WNS appears to be lower than other hibernating species occurring in similar areas (Langwig *et al.* 2012), and several studies have not found a decrease in Big Brown Bat activity following the arrival of WNS (Brooks 2011, Ford *et al.* 2011, Francl *et al.* 2012). The effect WNS would have on Big Brown Bats in Alberta, where hibernation behaviour may be different, is unknown.

6.2 Ecology

Considerable yearly and geographic variation has been observed in the timing of reproductive events for Big Brown Bats in southern Alberta, possibly the result of differences in weather conditions and roost quality (Lausen and Barclay 2006*a*, Barclay 2012). For example, in southern Alberta, the median birth dates of individuals in a colony varied by 24 days between adjacent years (Barclay 2012). Likewise, in southern Alberta, Big Brown Bats occupying buildings fledged approximately 1 to 2 weeks before those occupying natural roosts in rock crevices (Lausen and Barclay 2006*a*).

Although variable, pups are born from approximately mid-June to late-July in southern Alberta (Holloway 1998, Lausen and Barclay 2006*a*, Barclay 2012). Litters typically consist of one pup, but a small number have twins (Schowalter and Gunson 1979). Lactation lasts approximately 4 to 5 weeks (Kunz 1971). This suggests juveniles begin flying sometime between approximately mid-July through to the end of August. Some females will reach sexual maturity during their first year and reproduce the year after their birth, although most males do not reproduce until their second year (Barclay 2012). Mating is polygynous, and occurs near hibernacula during the autumn and winter, but pregnancy is delayed until the following spring (Kurta 1990). Hibernation lasts from approximately November to April (Nagorsen and Brigham 1993), but may emerge from hibernation and begin flying on warm nights throughout the winter (Lausen and Barclay 2006*b*).

6.2.1 Diet

Big Brown Bats are habitat generalists, and may use a variety of foraging habitats throughout the breeding season. Their size and echolocation structure makes them well adapted to foraging in open spaces, such as wetlands, open prairie, above forest canopies, and around human developments (Holloway 1998, Clare *et al.* 2014*b*). They consume insects from a wide range of insect orders, and the composition of their diet varies depending on insect availability (Brigham and Saunders 1990, Clare *et al.* 2014*b*, Valdez and O'Shea 2014). Several studies have reported exceptionally high amounts of Coleoptera (beetles) in their diet, which reflects a greater ability to consume hard-bodied insects (Brigham and Saunders 1990, Hamilton and Barclay 1998, Clare *et al.* 2014*b*). In southern Alberta, dietary studies regularly report that over half of their diet consists of beetles, with most of the remainder of their diet being Lepidoptera (moths), Hemiptera (true bugs), and Diptera (true flies) (Brigham and Saunders 1990, Hamilton and Barclay 1998, Holloway 1998). Bats foraging in grazed pasture on the prairies may feed extensively on beetles attracted to cattle dung (Arbuthnott and Brigham 2007). However, other insect orders may dominate during certain years or seasons, and juveniles may select fewer beetles in preference for softer bodied insects (Hamilton and Barclay 1998). Clare *et al.* (2014) used molecular methods to address biases that may result from the greater detectability of beetles in conventional dietary studies. Their results confirm that beetles are an important component of the diet of Big Brown Bats. Nonetheless, Diptera and Lepidoptera combined typically formed a greater proportion of the diet, suggesting the species is not necessarily a beetle specialist. Valdez and O'Shea (2014) found that bats in Colorado fed primarily on beetles from late May to early August, but shifted to feed primarily on seasonally abundant migratory Army Cutworms (*Euxoa auxiliaris*) during early spring and fall.

6.3 Habitat Requirements

6.3.1 General

Big Brown Bats are habitat generalists, and use a wide variety of roost types across their range in Alberta. Buildings, rock crevices, and tree cavities are used to varying extents, depending on availability (Schowalter and Gunson 1979, Kalcounis and Brigham 1998, Agosta 2002, Lausen and Barclay 2002). Along with the Little Brown Myotis, they are among the most common bat found occupying buildings (Schowalter and Gunson 1979). Maternity colonies in buildings are typically smaller than those observed for Little Brown Myotis. Most colonies in Alberta range between 10 to 80 individuals, but may be as high as 1,000 (Schowalter and Gunson 1979). Big Brown Bats are the only species in Alberta known to regularly use buildings as hibernacula (Schowalter and Gunson 1979); although, the importance of buildings compared to natural hibernacula is unknown.

6.3.2 Foraging Habitat

Foraging habitat for Big Brown Bats across much of the prairie region of southern Alberta appears to be associated with riparian zones (Brigham and Saunders 1990, Wilkinson and Barclay 1997, Holloway and Barclay 2000). Holloway and Barclay (2000) found that Big Brown Bats along the South Saskatchewan River rarely foraged in open prairie habitats farther than 1 km from the river, and foraging activity increased as distance to the river decreased. Within these riparian zones, activity was concentrated near springs, along the river itself, and along steep coulees. Treed river habitats, in particular, were associated with higher foraging activity than areas of the river where trees were absent. This pattern is likely influenced by the distribution of insect prey, which was observed to be much higher along the river and near springs than open prairie, as well as by the location of potential roosting habitat, such as occurs along steep coulees. Similarly, Wilkinson and Barclay (1997) found bats from two colonies in Medicine Hat foraged mostly within the South Saskatchewan River valley, and rarely within the city or adjacent prairie outside of the river valley. These results are consistent with observations of Big Brown Bats using prairie habitats in more southern regions of the United States, where one study found foraging activity to be more than five times greater in areas near water or treed edges than in open prairie (Everette *et al.* 2001).

Foraging in non-riparian habitats is more common in some areas of their range, possibly the result of greater tree cover and/or topographic variability that provides greater shelter from the wind. In the Cypress Hills, foraging commonly occurs along the Battle Creek valley, but also includes cattle pastures outside of the riparian zone (Arbuthnott and Brigham 2007). In these areas, cattle dung appears to result in a higher availability of beetles, which are important prey for Big Brown Bats. Urban areas and residential developments in rural areas are also used as foraging habitat by Big Brown Bats (Agosta 2002). Foraging on flying insects attracted to street or yard lights is commonly reported (Agosta 2002), but appears more prevalent in rural areas where insects are concentrated around relatively few lights (Geggie and Fenton 1985).

6.3.3 Roosting Habitat

Big Brown Bats in western Canada use a wide range of structures as roosts, including rock crevices (Holloway 1998, Lausen and Barclay 2002), tree cavities (Brigham 1991, Kalcounis and Brigham 1998, Vonhof and Gwilliam 2007), buildings (Schowalter and Gunson 1979, Hamilton and Barclay 1994), and possibly bridges (Davis and Cockrum 1963). Roost use appears to be opportunistic, and varies by region depending on the availability and relative quality of different roosting structures. However, the high frequency of building roosts in Alberta and across much of their North American range suggests that these are important roosting habitats for the species, and in some areas may be the primary roosting habitat available (Schowalter and Gunson 1979, Agosta 2002). Large deciduous trees are also important roosting habitat where they are available (Kalcounis and Brigham 1998). However, on the open prairies of southern Alberta, most natural roosting habitat occurs in river valleys, where steep eroded terrain creates rock crevices suitable for roosting (Holloway 1998, Lausen and Barclay 2002).

Bats occupying rock crevices and tree roosts frequently switch roosts, including during the breeding season (Lausen and Barclay 2002, Willis and Brigham 2004). The exact reason for this behaviour is unclear, but appears to provide a number of benefits, including maintaining social networks within the colony and adapting to changes in local conditions and reproductive requirements (Lausen and Barclay 2003, Willis and Brigham 2007). Several roosts are therefore required within an area to support the roosting requirements of Big Brown Bats roosting in natural rock and tree crevice roosts. Colonies in buildings typically have a higher degree of fidelity to a single maternity roost (Hamilton and Barclay 1994, Agosta 2002, Lausen and Barclay 2006*a*).

In southern Alberta, day roosts in either rock crevices or buildings are often also used as night roosts (Wilkinson and Barclay 1997, Holloway 1998). However, night roosts may be more commonly used by males, which do not need to care for young and often travel farther to forage. In other areas of Canada, separate night roosts are commonly used by maternity colonies that day roost in buildings (Brigham 1991).

6.3.4 Maternity Roosts

Maternity colonies along the South Saskatchewan River in southeastern Alberta are frequently reported to be in sandstone crevices along southeast facing vertical slopes (Holloway 1998, Lausen and Barclay 2002). Three main rock roost types have been reported: (1) long deep cracks along vertical slopes; (2) slab roosts (where a layer of rock has partially separated, created a relatively thin exterior wall) (Figure 1); and (3) erosion tubes (a hollow created by running water) (Holloway 1998, Lausen and Barclay 2002). Crevices used by reproductive females are along more vertical surfaces and have smaller openings than random crevices, likely to reduce the risk of predation (Lausen and Barclay 2002). Holloway (1998) reported that cracks used as roosts averaged 3.9 cm wide and 74.9 cm long. Big Brown Bats in the South Saskatchewan River valley appear to rarely use trees, despite large cottonwood trees being present (Holloway 1998, Lausen and Barclay 2002).

In the Cypress Hills, Saskatchewan, Big Brown Bats maternity colonies are nearly exclusively in the cavities of large-diameter living and dead Trembling Aspen (Kalcounis and Brigham 1998, Willis *et al.* 2006). Aspen roosts with larger cavities, which are typically those with crevices or multiple holes, had larger maternity colonies and were preferred over those with smaller cavities. The majority of roost cavities were originally excavated by sapsuckers and other woodpeckers (Kalcounis and Brigham 1998). Trembling Aspen in the Cypress hills were reused over multiple years, and most suitable cavities showed signs of use by bats (Willis and Brigham 2003, Willis *et al.* 2006).

Big Brown Bats in Alberta commonly use buildings as maternity roosts when they are available (Hamilton and Barclay 1994, Lausen and Barclay 2006*a*). Building roosts have been associated with earlier maturity than those using natural roosts, and may provide superior thermal properties and predator protection than natural roosts, possibly leading to greater reproductive success (Lausen and Barclay 2002). A variety of buildings may be used by Big Brown Bats, such as houses, industrial buildings, schools, and barns (Hamilton and Barclay 1994, Pybus 1994).

Females typically raise their young in maternity colonies. However, roost switching is common, and group size and composition may frequently change during the course of the breeding season (Lausen and Barclay 2002, Willis and Brigham 2004). For example, reproductive female bats roosting in tree cavities in the Cypress Hills, Saskatchewan, averaged 18.1 individuals (range 1 to 45), and switched roosts on average every 1.7 days (range 1 to 4.5 days) (Willis and Brigham 2004). Bats roosting in rock along the South Saskatchewan River had an average group size of 8.25 individuals (range 1 to 37), and switched roosts on average every 2.01 days (range 1 to 7; median: 1 day) (Lausen and Barclay 2002). Maternity colonies located in old, red-brick schools in southern Alberta supported over 100 individuals, and were reused over a period of at least 6 to 8 years (Hamilton and Barclay 1994, Barclay 2012). Bats roosting in buildings are known to show stronger roost fidelity than those roosting in tree or rock crevices, and if roost switching does occur, is often restricted to other sites within the same building (Lausen and Barclay 2006*a*). In the southern Alberta study, female bats during the pregnancy and lactation period spent 77% and 82%, respectively, of their days using the school maternity colony (Hamilton and Barclay 1994). When not in the primary maternity colony, bats roosted in nearby cliffs, industrial buildings, and houses.

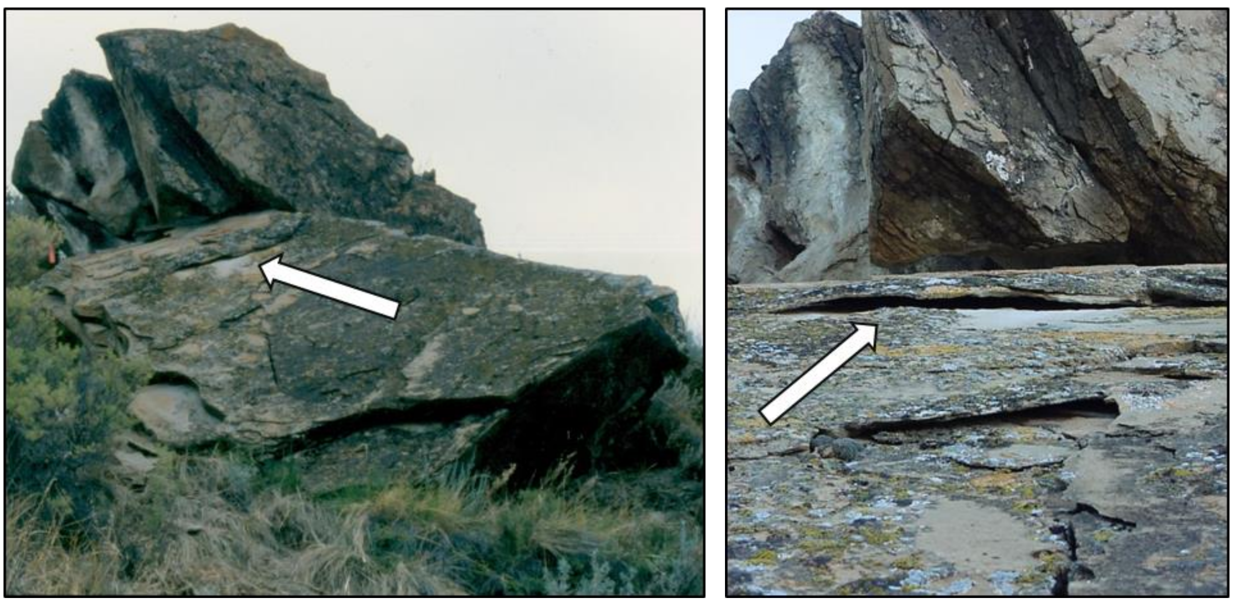

Figure 1. Slab (horizontal) rock-roost used by both Big Brown Bats and Western Small-footed Myotis within the South Saskatchewan River valley in Alberta. Right image is a close-up view of the same roost. Arrows point to roost entrance. Photos courtesy of Cori Lausen.

6.3.5 Hibernacula

Deep rock crevices in river valleys appear to be important hibernacula for Big Brown Bats in prairie environments (Figures 2 and 3; Lausen and Barclay 2006b; Baerwald, B pers. comm.). Lausen and Barclay (2006) tracked three Big Brown Bats during the winter to two hibernacula along a tributary to the Red Deer River, both of which were in badland terrain along steep slopes. One hibernaculum was a deep crevice in a boulder with an opening 14 cm high and 1 to 2.5 cm wide, and the other was a tubular erosion hole in solidified mud, which was at least 3.6 m deep and a 7 cm x 5 cm oval opening. Three additional hibernacula were also located in this region, and all were in deep, narrow crevices (0.5 to 2.0 m long) of mudstone/sandstone cliffs (Baerwald, B., pers. comm.). Hibernacula in the Red Deer River valley are high above level ground and have southern aspects (Lausen and Barclay 2006*b*). The use of rock crevices for hibernation is also consistent with behaviours observed elsewhere in their range. In Colorado, Big Brown Bats appear to move into higher elevation mountain habitats to hibernate in deep rock crevices (Neubaum *et al.* 2006). Locations with cool, stable temperatures that do not drop below freezing appear to provide optimal conditions for hibernation. A small number of Big Brown Bats in northern Alberta also appear to hibernate in caves (Reimer *et al.* 2014), but records elsewhere in the province are lacking, suggesting this is not a widespread behaviour.

Large numbers of Big Brown Bats hibernate in buildings in at least some portions of their North American range (Schowalter and Gunson 1979, Perkins *et al.* 1990, Whitaker and Gummer 1992, Nagorsen and Brigham 1993). Schowalter and Gunson (1979) provided several anecdotal examples of winter observations that suggests the species may commonly use building hibernacula in Alberta, a behaviour not commonly reported for other species. Buildings appeared to be avoided in preference for rock crevice hibernacula in Colorado (Neubaum *et al.* 2006). However, inadequate information exists in Alberta to evaluate the importance of building hibernacula for bats in the province.

Figure 2. Hibernacula used by a female Big Brown Bat along the Red Deer River valley (arrow points to entrance). Right image is a close-up view of the same hibernacula. Photos courtesy of Cori Lausen.

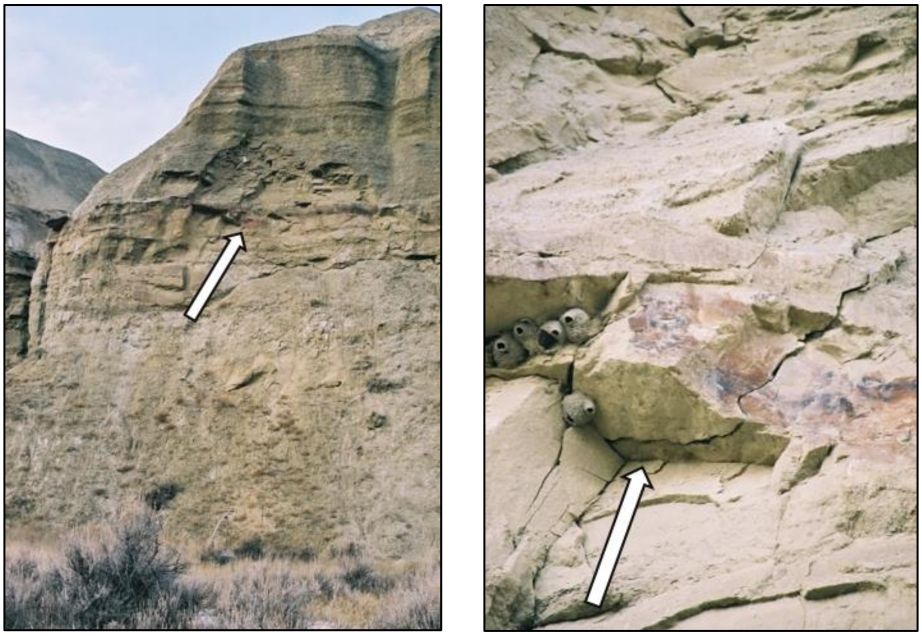

Figure 3. Hibernacula used by a male Big Brown Bat along the Red Deer River valley (arrows point to entrance). Right image is a close-up view of the same hibernacula. Photos courtesy of Cori Lausen.

6.3.6 Area Requirements

Big Brown Bats are adapted to fast flight in open spaces, and can span long distances in search of water, food, and roosting habitat. The home range size depends on several factors, such as the quality and configuration of required resources, energy requirements, and the roosting and foraging strategy being used. Wilkinson and Barclay (1997) compared foraging areas of a sample of male and female Big Brown Bats from two building colonies in southeastern Alberta, both located at schools in Medicine hat, within 1 km of the South Saskatchewan River. They found the males had significantly larger foraging areas (mean 5.09 km^2) than females (mean 2.71 km^2), which tended to forage closer to the maternity colony and were less likely to make long-distance foraging bouts.

Bats roosting in buildings may use a single structure for the duration of the breeding season (Wilkinson and Barclay 1997). However, colonies using natural structures tend to regularly switch roosts, and effectively establish roosting areas within which they alternate among available roosts. Big Brown Bats roosting in rock crevices along the Red Deer River valley roosted within a 1.25 km length of the river valley (Lausen and Barclay 2002). Bat colonies in the Cypress Hills showed high fidelity to non-overlapping roosting areas that were each less than 2 km^2 (Willis and Brigham 2004).

Much more variability in area requirements has been reported in areas outside of Alberta. In the southeastern United States, three Big Brown Bats roosting in a building had an average home range size (excluding outer 5% of observations) of 2,906 ha, and had a maximum foraging distance of 5 km (Menzel *et al.* 2001). A building roosting colony in Ontario foraged an average of 0.9 km, and up to 4.1 km, from their day roost and their foraging grounds (Brigham and Fenton 1986). Tree and rock roosting bats in British Columbia travelled an average of 1.8 km, and up to 4.4 km, between day roosts and foraging areas (Brigham 1991). Big Brown Bats using a prairie wildlife refuge in Colorado travelled an average of 13.8 km (range 9.2 to 18.8 km) from the point of capture to their building roost (Everette *et al.* 2001).

7 LITTLE BROWN MYOTIS

7.1 Background

Little Brown Myotis (*Myotis lucifugus*) occur across most areas of North America from Mexico to the northern extent of the boreal forest (Fenton and Barclay 1980). They are among the most common and widespread species in Alberta and across much of the rest of North America, including across large areas of the prairies (Schowalter *et al.* 1979, Vonhof and Hobson 2000, Hubbs and Schowalter 2003, Lausen 2004, 2006, Coleman and Barclay 2011). However, there is regional variation in abundance, and they are relatively uncommon in some prairie habitats, including at least a portion of the badlands along the South Saskatchewan River (Holloway and Barclay 2000). Schowalter *et al.* (1979) indicated that Little Brown Myotis appears to be less common in areas of the province dominated by solonetzic soils, and suggested the higher salinity of water bodies in these areas may result in reduced prey needed to support this species. Two subspecies are believed to occur in the prairie regions of southern Alberta: *M. l. lucifugus* occurs throughout the province, while *M. l. carissima* appears to be restricted to southern Alberta, including the Milk River area (Lausen 2007). However, the range of *M. l. lucifu*gus overlaps that of *M. l. carissima* and extensive interbreeding occurs in this region, suggesting subspecies designations are a product of historical genetic isolation between the two groups that may no longer be relevant (Lausen 2007).

Little Brown Myotis are listed as Endangered under the Species at Risk Act because of the continuing spread of white-nose syndrome from eastern North America. Population declines in excess of 90% have been documented in areas where the disease occurs (COSEWIC 2013). Little Brown Myotis in eastern North America are among the most affected by this disease and are at risk of regional extirpation (Frick *et al.* 2010). If introduced to Alberta, this disease has potential to cause a precipitous decline in the provincial bat population. Hibernacula are critical habitat for bats; however, known hibernacula in the province account for only a trivial portion of the overall population (Olson *et al.* 2011). This knowledge gap impedes protection measures for bat hibernacula, as well as white-nose syndrome surveillance and monitoring programs.

Fatalities of Little Brown Myotis at wind energy facilities may also be a conservation concern in some areas. Little Brown Myotis comprised about 6% of fatalities at select wind energy sites across North America (Arnett and Baerwald 2013). However, the species was a relatively minor component (i.e., < 1%) of fatalities at a site monitored in southern Alberta during fall migration (Baerwald and Barclay 2011). Although wind turbines kill fewer Little Brown Myotis relative to migratory bats, it may still be an important source of cumulative mortality for the species (Arnett and Baerwald 2013).

Their close association with people leaves them vulnerable to accidental and deliberate human-caused disturbance and mortality, such as from eviction, extermination, and entrapment. However, buildings provide warm, well protected environments for raising pups, and are likely critical resources for this species in human modified landscapes (Schowalter *et al.* 1979, Lausen and Barclay 2006*a*). Because of the large size of colonies, persecution or improper management of a few roosts could potentially have significant repercussions for the local bat population. Furthermore, new building designs that are better able to exclude bats likely have negative consequences for the species. The continued availability of suitable buildings, or other artificial structures, may be important for maintaining prairie populations.

7.2 Ecology

Females give birth to a single pup, or rarely twins, from approximately mid-June to late-July (Schowalter *et al.* 1979, Coleman and Barclay 2011). Pups begin flying and foraging for insects when they are about 18 days old, and are weaned at about 27 days old (Kurta *et al.* 1989). In southern Alberta, flying juveniles appear beginning about mid-July to August (Schowalter *et al.* 1979, Holloway 1998). Observations of hibernation are based mainly on studies at two cave hibernacula in the Rocky Mountains, and may not necessarily apply throughout the province. However, bats begin congregating (swarming) at these hibernacula by about the middle of August, and begin hibernating around the end of September (Schowalter *et al.* 1979, Schowalter 1980). Mating is polygynous and occurs during fall swarming and during winter hibernation, when males briefly arouse from hibernation to mate with torpid females. Pregnancy is delayed until the following spring (Fenton and Barclay 1980). Information from mountain habitats suggests that both male and female Little Brown Myotis in Alberta may not mate until their second year (Schowalter *et al.* 1979, Schowalter 1980). Emergence from hibernation occurs by about April to mid-May, and females begin appearing at their summer maternity roosts shortly thereafter (Schowalter *et al.* 1979).

7.2.1 Diet

Little Brown Myotis are opportunistic foragers, and have a diverse diet from several insect orders (Saunders and Barclay 1992, Holloway 1998, Clare *et al.* 2014*a*). However, they have a strong affinity to aquatic habitats, and their diets are influenced by the availability and timing of aquatic insect emergence (Fenton and Barclay 1980, Clare *et al.* 2014*a*). Prey selection along the South Saskatchewan River was dominated by Diptera (true flies) and Coleoptera (beetles) during the early summer (May and June), and by Diptera and Lepidoptera (moths) during the late summer (July and August) (Holloway 1998). The families Culicidae (mosquitos) / Chaoboridae (phantom midges) and Muscidae (flies) dominated the dipteran component of their diet, but

Muscidae was primarily consumed during the late summer. Similar results were reported for the Milk River, where diets were dominated by similar proportions of Lepidoptera, Diptera, and Coleoptera (Saunders and Barclay 1992). Although Lepidoptera were the most common prey for both Little Brown Myotis and Long-legged Myotis in the Milk River study, Little Brown Myotis consumed much greater proportions of Diptera and Coleoptera relative to Long-legged Myotis.

In a large scale study across Canada, the diet of Little Brown Myotis was dominated by Lepidoptera and Dipterans, and lower proportions of Ephemeroptera (mayflies), Trichoptera (caddisflies), and Coleoptera (Clare *et al.* 2014*a*). Two species of chironomids and two species of mayflies were the most common prey species. The diet shifts throughout the season, with dipterans forming the greatest proportion of the diet during the early summer (i.e., May to mid-June) and lepidopterans becoming relatively more common as the summer progresses (Clare *et al.* 2011, 2014*a*).

7.3 Habitat Requirements

7.3.1 General

Few species in Alberta have adapted as well to human activities as the Little Brown Myotis (Pybus 1994). They are often the most abundant species in urban areas, and form some of the largest colonies in buildings and other human structures (Coleman and Barclay 2011). Roost use appears to be opportunistic. Like the Big Brown Bat, they will use a wide range of human structures, rock crevices, and trees for roosting, but show a strong tendency to establish maternity colonies in buildings when suitable structures are available (Schowalter *et al.* 1979, Fenton and Barclay 1980). They are the most gregarious species in Alberta, with maternity colonies in buildings exceeding 1,000 individuals in some locations (Schowalter *et al.* 1979, Coleman and Barclay 2011). The spacious, warm, and well protected properties of buildings provide ideal locations for maternity colonies (Lausen and Barclay 2006*a*). For natural roosting populations, the tendency to form large colonies may restrict the range of roosts they use to larger structures capable of holding a greater number of individuals (Olson 2011, Olson and Barclay 2013). Few other bats in Alberta are as associated with aquatic habitats for foraging as the Little Brown Myotis (Fenton and Barclay 1980, Clare *et al.* 2014*a*). Buildings or natural roosts near large aquatic habitats (e.g., lakes, rivers) appear most likely to be used as maternity colonies, and are important resources for the species (Schowalter *et al.* 1979, Pybus 1994).

7.3.2 Foraging Habitat

Little Brown Myotis are opportunistic foragers and consume a variety of prey types across different habitats. They have a variety of foraging strategies and occupy both open and cluttered environments (e.g., around vegetation). However, they have a particularly strong association with aquatic habitats, where they forage extensively on swarms of aquatic insects (Belwood and Fenton 1976, Saunders and Barclay 1992, Holloway 1998, Clare *et al.* 2014*a*). They are among the most common species foraging around wetlands, lakes, and water courses in the province

(Schowalter *et al.* 1979). Although not extensively examined, foraging habitat on the prairies of southern Alberta likely includes a variety of aquatic habitats, especially those in riparian zones and areas where topography or tree cover provides shelter from the wind. Holloway and Barclay (2000) found bats rarely used open prairies habitats away from the riparian zone of rivers. However, their study did not examine activity around prairie lakes, sloughs and other aquatic habitats outside of the riparian zone and therefore may not provide a complete indication of the range of foraging habitats used by Little Brown Myotis.

Barclay (1991) suggested their primary strategy of hawking flying insects close to the surface of the water may limit their foraging window to periods of the night where temperatures are high enough to allow insects to fly, making colder high elevations less suitable for reproductive females that have higher energetic requirements. While males may be able to occupy lower quality foraging habitat due to their lower energetic requirements, females are most likely to occur where food availability is the highest (Barclay 1991).

7.3.3 Roosting Habitat

Little Brown Myotis have a flexible roosting strategy, and similar to Big Brown Bats, will opportunistically take advantage of available roosts (Fenton and Barclay 1980). Roost structures used on the prairies include tree cavities (Coleman and Barclay 2011), rock crevices (Holloway 1998), buildings (Schowalter *et al.* 1979, Kalcounis and Hecker 1996, Coleman and Barclay 2011), and bridges (Barclay pers. comm.). Although a variety of structures are used, reports of building roosts are especially common throughout their range, and may be the primary roosting structure used by reproductive female Little Brown Myotis on the prairies (Schowalter *et al.* 1979, Fenton and Barclay 1980, Coleman and Barclay 2011). Across the prairies of southern Alberta, most non-building roosts are located in trees and rock crevices, which are most often found within riparian zones (Holloway and Barclay 2000, Coleman and Barclay 2011). If using tree-roosts, old, large-diameter decaying trees are selected, which most often occurs in older forests or old forest remnants (Crampton and Barclay 1998).

Non-maternity roosts include a broader range of roost types than those used by maternity colonies. Males and non-reproductive females appear to have greater flexibility in selecting roosts, and are more likely to occupy roost types that would be avoided by reproductive females. For example, male Little Brown Myotis occupying a forested regions of New Brunswick commonly roosted alone in coniferous or deciduous trees and snags, while most females apparently roosted in nearby buildings (Broders and Forbes 2004). Because males generally roost alone or in small groups, they may be better able to use smaller, more abundant roost structures in their environment than reproductive females (Olson and Barclay 2013, Fabianek *et al.* 2015). For example, males may be better able to take advantage of smaller diameter trees, or species that produce smaller cavities when they decay (e.g., coniferous species).

Although presumably not suitable for maternity colonies, the use of exposed roosts on buildings appears to be relatively common in Alberta during August and September, coinciding with the dispersal of juveniles away from maternity colonies (Riskin and Pybus 1998). During this time, juveniles, and occasionally adults, may lack familiarity with accessible enclosed roosts and instead use exposed roosts on buildings. Exposed roosts tend to be under an overhang, at least 2 m above the ground, are more likely to be in corners, and are located on brick or other rough textured surfaces.

With the possible exception of females nursing pups, Little Brown Myotis appear to commonly use night roosts separate from their day roosts (Barclay 1982, Perlmeter 1995, Holloway 1998). Females appear likely to use communal night roosts, while males are more likely to roost alone (Perlmeter 1995). Along the South Saskatchewan River, night roosts included the same roosts as used during the day, but also included small caves where mixed-species groups would roost together during the night (Holloway 1998). Bats roosting in buildings may have separate night roosts, but behaviour appears to vary by colony (Barclay 1982). A maternity colony in Ontario commonly used a separate day and night roost during the pregnancy period, but switched to use a single roost once they began nursing pups (Barclay 1982). Another nearby building colony used a single structure as both a day and night roost regardless of whether they were pregnant or lactating. Concrete bridges also appear to be commonly used as night roosts by both male and female Little Brown Myotis, and may support multiple colonies, and multiple species, occurring in an area (Perlmeter 1995, Adam and Hayes 2000).

Female Little Brown Myotis form the largest maternity colonies seen in Alberta, at times exceeding 1,000 individuals (Schowalter *et al.* 1979, Coleman and Barclay 2011). Maternity colonies typically use a single building, although more than one building may be used by larger colonies, and individuals typically move around within roosts (Schowalter *et al.* 1979). Additional structures may also be required for use as night roosts (Barclay 1982). Few natural roosts can support large colonies. However, maternity colonies in natural roosts are highly dynamic and frequent roost switching allows bats to change the size and location of maternity colonies throughout the breeding season (Olson and Barclay 2013). Although not altogether at one time, bats roosting in trees or rock crevices may still roost with hundreds or thousands of individuals during the course of the summer (Olson 2011). This behaviour requires bats using natural roost structures to have many available roosts to select among within their roosting area.

7.3.4 Maternity Roosts

Buildings are commonly used by maternity colonies throughout most of Alberta, especially in more densely developed locations (Schowalter *et al.* 1979, Coleman and Barclay 2011) (Figure 4). Building roosts include occupied and abandoned houses, cottages, sheds, and barns (Schowalter *et al.* 1979). Occupied buildings appear to be favoured sites for maternity colonies (Schowalter *et al.* 1979), possibly because of artificial heating. Little Brown Myotis forage extensively over aquatic habitats, and building roosts are often located in close proximity to lakes and other aquatic habitats. Bats do not chew entrances or otherwise modify their roosts, so buildings must have some sort of entrance or structural defect that allows access into warm protected crevices or chambers. Such locations include attics, under shingles or siding, within hollow walls, behind shutters, within or behind chimneys, or any other elevated sheltered location that bats can access (Pybus 1994).

In regions of the province where buildings are uncommon, maternity colonies are located in tree and rock crevices. Riparian zones, especially areas of extensive badlands, often have sedimentary rock that erodes and creates crevices suitable for maternity colonies. In a mostly undeveloped portion of the South Saskatchewan River valley, maternity colonies were found in sandstone crevices of southeast facing cliffs and coulees (Holloway 1998). Roosts in this region included small crevices along vertical slopes and cliffs, water erosion cracks, and small caves. Likewise, Saunders (1989) found a Little Brown Myotis maternity colony under a crevice in a south-facing sandstone cliff along the Milk River valley in southern Alberta (Figure 7). The Milk River colony also contained Long-legged Myotis, which roosted in mixed clusters with Little Brown Myotis.

Away from riparian badlands or mountain habitats, most natural maternity roosts in Alberta are likely to be in the cavities of trees, especially of large-diameter deciduous species (e.g., *Populus* spp.) (Kalcounis and Hecker 1996, Coleman and Barclay 2011, Olson and Barclay 2013). In the boreal forest, Little Brown Myotis maternity colonies are commonly in Trembling Aspen and Balsam Poplar (Figure 5) (Crampton and Barclay 1998, Olson and Barclay 2013), as well as buildings (Olson 2011). Tree cavities used by bats in northern Alberta are often created by elongated vertical cracks (e.g., frost cracks) that open into large internal cavities, but various other defects are also used, including woodpecker holes, knot holes, sloughing bark, and breakages (Olson 2011). This is similar to a study in the Cypress Hills, where maternity colonies were in either buildings or Trembling Aspen (Kalcounis and Hecker 1996). Typically, only large diameter trees are suitable for maternity colonies, with small diameter trees (roughly < 30 cm diameter) rarely used (Crampton and Barclay 1998, Olson and Barclay 2013).

Studies of tree-roosting Little Brown Myotis maternity colonies in Alberta report residency times, before bats switch roosts, ranging from 1.5 days (range 1 to 6 days) (Olson and Barclay 2013) to 3.7 days (Crampton and Barclay 1998). Cavities in large diameter trees may support in excess of 100 individuals, with a maximum maternity colony size of 387 bats reported at one site in northern Alberta (Olson and Barclay 2013). Small diameter trees (e.g., < 45 cm DBH) may not be able to support groups larger than 100 adults. However, colonies may rarely approach this number in some parts of their range. For example, Crampton and Barclay (1998) found tree-roosting maternity colonies averaged 15.3 bats, and never more than 60 bats. A small sample of Little Brown Myotis roosting along the South Saskatchewan River had a mean group size of 24.5 (range 13 to 41 individuals) (Holloway 1998). Saunders (1989) found approximately 94 bats (of mixed species) roosting under a sandstone crevice along the Milk River. These bats used the roost for at least 22 consecutive days during the summer, and only left after being disturbed by a park visitor.

Figure 4. A barn roost used by a Little Brown Myotis in Alberta. Right two photos are an inside view of the barn showing the roosting group and a pile of guano below the roost location. Photos courtesy of Cory Olson.

Figure 5. Trembling Aspen (left) and Balsam Poplar (right) roost trees used by Little Brown Myotis maternity colonies in Alberta. Arrow points to roost entrance. Photos courtesy of Cory Olson.

7.3.5 Hibernacula

Caves and mines are often used as hibernacula by Little Brown Myotis throughout their range (Fenton and Barclay 1980). In Alberta, Little Brown Myotis are known to hibernate in Cadomin Cave (near Hinton) and Wapiabi Cave (in Nordegg), and a few other caves in the Rocky Mountains and Wood Buffalo National Park (Hobson 2014). However, the largest Alberta hibernacula still represents fewer than two thousand individuals (Hobson 2014), and all these caves combined represents a very small proportion of the overall bat population in the province (Olson *et al.* 2011). Either the primary cave hibernacula for bats in Alberta have not been located, or bats are hibernating in structures other than caves and mines. Some bats in Alberta, particularly Big Brown Bats, are known to hibernate in deep rock crevices along river valleys and in mountainous regions (Lausen and Barclay 2006*b*, Neubaum *et al.* 2006). Similar hibernacula could be used by Little Brown Myotis, but this behavior has not yet been documented. Buildings do not appear to be commonly used as hibernacula by Little Brown Myotis (Fenton and Barclay 1980).

7.3.6 Area Requirements

Little Brown Myotis can have expansive home ranges, including a variety of habitat patches and cover types (Bergeson *et al.* 2013). Similar to other bats, the area requirements depend on the configuration of drinking water, as well as foraging and roosting habitat, and will depend on sex, age, reproductive status, and foraging strategy (Henry *et al.* 2002, Broders *et al.* 2006). Little Brown Myotis in New York had a home range (excluding outer 5% of observations) of 143 ha (Coleman *et al.* 2014). Average foraging area (excluding outer 5% of observations) by adult females, of various reproductive stages, was 515 ha (range 107 to 994 ha) in Illinois (Bergeson *et al.* 2013). A river island population in Quebec had a mean home range size (excluding outer 5% of observations) of 30 ha during the pregnancy period, but then decreased to 18 ha during the lactation period (Henry *et al.* 2002). Tree-roosting male Little Brown Myotis, in New Brunswick, had an average minimum roosting area (including 100% of observations) of 3.9 ha, and a minimum foraging area of 52 ha (Broders *et al.* 2006).

Little Brown Myotis show a variety of roosting strategies, including the use of buildings and bridges, rock roosts, and tree cavities (Schowalter *et al.* 1979, Holloway 1998, Olson and Barclay 2013). Large permanent structures such as buildings may be reused over long periods, and therefore roosting areas may be quite small. However, Little Brown Myotis using trees frequently switch roosts (Olson and Barclay 2013). In the boreal forest, tree-roosting colonies of reproductive female Little Brown Myotis had roosting areas as small as 20 ha and as large as 300 ha, with distances between successive roosts ranging from 50 to 1,729 m (Olson 2011). These results are consistent with reports in Illinois, where individuals roosting in a combination of tree cavities and buildings moved an average of 815 m (range 4 to 2,960 m) between consecutive roosts (Bergeson *et al.* 2015).

8 LONG-EARED MYOTIS

8.1 Background

Long-eared Myotis (*Myotis evotis*) occur across western Canada, and much of the western United States (Manning and Jones 1989). Their northern range in Canada includes montane forest of the Northwest Territories (Lausen *et al.* 2014). In Alberta, they occur throughout the Rocky Mountains and most of the southern third of the province, approximately coinciding with the Grassland Natural Region and the southern extent of the Parkland Natural Region (Lausen 2006, Natural Regions Committee 2006).

Very little is known regarding population trends or conservation threats in Alberta. However, on the prairies, their distribution is most associated with riparian areas, where they commonly roost in rock crevices (Holloway and Barclay 2000). Destruction or degradation of riparian zones, especially cottonwood forest, is an important conservation concern for the species. Long-eared Myotis are not within the known range of white-nose syndrome, so their susceptibility is not currently known. A small number are killed at wind energy facilities in North America, but appears to be at a much lower rate relative to other species (Arnett and Baerwald 2013).

8.2 Ecology

Pups are born from about the end of June to mid-July in southern Alberta (Holloway 1998, Chruszcz and Barclay 2002). Reproductive events of Long-eared Myotis in the mountains west of the prairies were noted to be about 10 days later, with pups being born about the last half of July (Solick and Barclay 2006*b*). Females typically give birth to a single pup per year (Solick and Barclay 2006*a*). Juveniles begin flying about the last two weeks of July in southern Alberta. Bats may begin dispersing from their natal territories after young are weaned. However, at least some Long-eared Myotis may mate and overwinter in prairie river valleys, possibly near their summer range (Lausen and Barclay 2006*b*). Mating behavior is largely unknown, but likely occurs during the fall or winter, similar to other Alberta bats (Barclay 1993). Pregnancy is delayed until emergence from hibernation in the spring.

8.2.1 Diet

Most studies report that Lepidoptera (moths) comprise a particularly large component of their diet (Barclay 1991, Holloway 1998). However, like other bats, they opportunistically forage across several orders of insects, as well as spiders. In one study in southern Alberta, almost half the diet of Long-eared Myotis was Lepidoptera (moths), with most of the remainder split between Coleoptera (beetles) and Diptera (midges) (Holloway 1998). In Oregon, moths were also the most common group, with Araneae (spiders), Hemiptera (true bugs), and Coleoptera also being substantial components (Ober and Hayes 2008). In Idaho, Lepidoptera were also most often consumed, followed by Coleoptera and Hemiptera (Lacki *et al.* 2007).

8.3 Habitat Requirements

8.3.1 General

Like all bats, Long-eared Myotis require suitable foraging and roosting habitat and access to drinking water (Kurta 2000). They are capable of long-distance flights, but their wing morphology and foraging strategy is likely better suited to a short-distance foraging strategy. As a result, the close proximity of required resources is likely important for their occurrence in an area. Roost selection appears more likely to occur in areas near available drinking water in at least some parts of their range (Snider *et al.* 2013). In open prairie habitats in Alberta, activity is concentrated in riparian zones, where roosting and foraging habitat, as well as drinking water is readily available (Holloway 1998). Features such as springs, coulees, cliffs, boulders, sandstone crevices, trees, shrubby vegetation, and the river itself creates heterogeneous landscapes providing habitat for individual bats, as well as their insect prey.

Long-eared Myotis are capable of hawking insects in flight, but are especially well adapted at gleaning insects off surfaces (Faure and Barclay 1994). The extensive use of gleaning to capture prey allows foraging bouts to continue after temperatures drop below levels that permit insect flight. Longer foraging bouts may allow the species to use habitats inhospitable to aerial hawking species (e.g., cold mountain habitats) (Barclay 1991). The morphology of prairie populations appears better suited to hawking insects than mountain populations, suggesting both foraging strategies may be important (Solick and Barclay 2006*b*). Low-wing loading and maneuverable flight appear to also allow Long-eared Myotis to access habitats that few other bats in Alberta have been observed to use. For example, roosts near the surface of the ground are often used, including tree stumps, erosion holes, and rock piles (Vonhof and Barclay 1997, Solick and Barclay 2007, Nixon *et al.* 2009).

8.3.2 Foraging Habitat

Like many bat species, Long-eared Myotis activity is generally highest in areas near water, which support abundant, diverse insect prey (Holloway and Barclay 2000, Waldien and Hayes 2001). However, the species does not necessarily forage over water, but rather forages over terrestrial habitats adjacent to water (Waldien and Hayes 2001). Trees, especially those in riparian habitats, are particularly important because they attract insects and provide a substrate from which resting insects can be gleaned (Holloway and Barclay 2000, Waldien and Hayes 2001). On the prairies of southern Alberta, high foraging activity has been observed around riparian cottonwood stands, while nearly no activity occurs in relatively homogenous open upland prairies outside of the riparian zone (Chruszcz 1999, Holloway and Barclay 2000).

8.3.3 Roosting Habitat

A variety of structures are used for roosts, including rock crevices (Holloway 1998, Chruszcz and Barclay 2002, Solick and Barclay 2006*b*, Nixon *et al.* 2009), trees, snags, stumps and downed logs (Vonhof and Barclay 1997, Waldien *et al.* 2000, Arnett and Hayes 2009), and occasionally buildings (Nixon *et al.* 2009). However, in southern Alberta, most reported roosts are in rock crevices and erosion holes along riparian badlands (Holloway 1998, Chruszcz and Barclay 2002, Nixon *et al.* 2009). Similar roosts are used for both day roosts and night roosts in southern Alberta (Holloway 1998). Other roosts may be used outside of riparian areas in Alberta. However, this has not been examined, and the species does not appear to be a common prairie resident in locations where badland terrain is unavailable (Coleman and Barclay 2012).

Although roosts of a variety of heights are used, Long-eared Myotis have a particularly strong tendency to select roosts near or below the ground, including under piles of rock debris, tree stumps, downed logs, erosion holes, and small boulders (Vonhof and Barclay 1997, Holloway 1998, Waldien *et al.* 2000, Solick and Barclay 2007, Arnett and Hayes 2009). This behaviour is likely a product of their wing morphology, which makes them better adapted to taking off from the ground. Roosts near the ground may increase the risk of disturbance from vehicles or foot traffic; however, they are generally in locations of sparse vegetation or rugged terrain that are unattractive to livestock (Barclay pers. comm.).

8.3.4 Maternity Roosts

Maternity roosts used by Long-eared Myotis on the prairies include sandstone boulders, crevices along cliffs, as well as erosion cavities or channels that form in sandstone or mudstone terrain (Holloway 1998, Chruszcz and Barclay 2002, Solick and Barclay 2007, Nixon *et al.* 2009). Buildings are also used as maternity roosts (Schowalter 1978), but generally little is known about the frequency of use, or importance, of these roost structures. Reproductive females are typically solitary on the prairies. Occasionally, they will roost with 1 to 2 other individuals, or less commonly, in groups of up to 8 or more (Holloway 1998, Nixon *et al.* 2009). Building colonies may be larger, with one in Alberta estimated to have 15 to 20 individuals (Schowalter 1978).

The properties of maternity roosts used on the prairies differs across river systems, and by reproductive status. In badland terrain along the South Saskatchewan River valley, maternity roosts primarily occur in sandstone boulders situated along slopes or on level ground (Holloway 1998, Chruszcz and Barclay 2002, Solick and Barclay 2007). However, in this area, pregnant bats typically select roosts under a thin slab of rock bounding the larger body of a boulder, apparently to take advantage of solar heating during the daytime. In contrast, lactating females primarily roost in deep vertical splits that run perpendicular to the ground, which leaves two large sections of rock (Figure 6). These roosts are particularly effective at buffering fluctuations in ambient conditions outside the roost, which is important for ensuring the survival of young left behind in the roost during foraging bouts. Roosts in boulders tend to be low to the ground (i.e., < 1 m), and may be in both large and small boulders (Holloway 1998). Individuals in the South Saskatchewan River valley also roost within erosion cracks descending into the ground along flat slopes, as well as small crevices along sandstone cliffs. The tendency to use boulders appears to be specific to certain landforms and is not consistent across the prairies. In the Red Deer River valley, roosting primarily occurs in erosion cavities and channels that developed in the ground along the slopes of the river and adjacent coulees (Nixon *et al.* 2009). These appear similar to those used by Western Small-footed Myotis (Lausen 2007) (Figure 8).

Maternity roosts in the Rocky Mountains of southwestern Alberta were found among rock fields along steep south facing slopes. In this area, Long-eared Myotis formed small colonies hidden among loose boulders or talus stones (Solick and Barclay 2006*a*). These roosts are typically near or below the ground, and rarely more than 1 m above the surface. Pregnant females have also been observed roosting under the bark of decaying White Spruce (*Picea glauca*) and Lodgepole Pine (*Pinus contorta*) in the mountains, but this appears less common than rock crevice roosts (Solick and Barclay 2006a).

In forested habitats, the Long-eared Myotis is unique in its tendency towards roosting in conifer stumps and downed logs (Vonhof and Barclay 1997, Waldien *et al.* 2000, Arnett and Hayes 2009). Taller, large diameter conifer stumps with abundant sloughing bark are most likely to be used. Pine stump roosts were frequently used in British Columbia (Vonhof and Barclay 1997). When available, tall, large-diameter snags appear to be preferred over stumps (Waldien *et al.* 2000, Schwab 2006, Arnett and Hayes 2009). In British Columbia, use of stump roosts was mostly by males and non-reproductive females (Vonhof and Barclay 1997), suggesting different structures were used for maternity roosts. However, use of stumps by reproductive females has been noted in western Oregon (Waldien *et al.* 2000).

Figure 6. Vertical crevice roost in a sandstone boulder, typical of those used by lactating Long-eared Myotis along the South Saskatchewan River (photo courtesy of Cori Lausen).

8.3.5 Hibernacula

Very little is known about the hibernation ecology of Long-eared Myotis. Echolocation calls were detected outside of potential hibernacula during the winter along the Red Deer River (Lausen and Barclay 2006*b*). This suggests hibernation likely occurs in the area, possibly in deep rock crevices or erosion holes similar to those observed being used by Big Brown Bats. Mines and caves may also be used as hibernacula (Swenson and Shanks 1979, Manning and Jones 1989, Hendricks 2000); however, reports are uncommon and usually consist of small numbers, suggesting hibernation may more commonly occur in other structures. Individuals have not been found using cave hibernacula in Alberta, despite the species being present in mountain habitats where known cave hibernacula of other bat species are present.

8.3.6 Area Requirements

Long-eared Myotis occupying rock and tree roosts have particularly high rates of roost switching. Individuals typically only use a roost for 1 or 2 days, and rarely more than 4 days, before relocating to another site (Vonhof and Barclay 1997, Holloway 1998, Rancourt *et al.* 2005, Solick and Barclay 2006*a*, Nixon *et al.* 2009). Although individual roosts may only be used for a short period, individual bats nonetheless have high fidelity to relatively small roost areas (Rancourt *et al.* 2005, Solick and Barclay 2006*a*, Nixon *et al.* 2009). In the Red Deer River valley, individual roost areas were typically less than 2 ha (range 0.1 ha to 4.7 ha) (Nixon *et al.* 2009). These roost areas corresponded to an average distance between successive roosts that ranged from 30 m for lactating females to 91 m for pregnant females (maximum distance = 812 m). Solick and Barclay (2006) also found the species to have small roosting areas in the Rocky Mountains, with most bats in their study roosting within a single rock field and moving an average of only 50 m between consecutive roosts.

Other studies, outside of Alberta, have reported more dispersed roost areas for this species. For example, the average distance between consecutive roosts was 149 m for a study of rock-roosting bats in northeastern Washington (Rancourt *et al.* 2005) and 424 m (range 31 to 1,427 m) for a study in southwestern Colorado (Snider *et al.* 2013). Bats in Alberta occupying habitats with more dispersed roost structures (i.e., outside of riparian badlands or rock fields) may require larger areas for roosting, similar to that observed elsewhere in North America.

The size of foraging areas is less well understood. However, their wing morphology is best adapted to a slow, short-range foraging strategy (Norberg and Rayner 1987), suggesting the size of their foraging range is likely to be on the smaller end for Alberta bats. In Oregon, adult female Long-eared Myotis were active in an area that averaged 38.3 ha per night (Waldien and Hayes 2001). The center of these activity areas averaged 518 m from their day roost, but only 73 m to open water, which suggests most foraging occurred in proximity to water. Radio-telemetry studies report average distances between capture locations and roosting areas ranging from 0.66 km in western Oregon (Waldien *et al.* 2000) to 2.0 km in southwestern Colorado (Snider *et al.* 2013).

9 LONG-LEGGED MYOTIS

9.1 Background

Long-legged Myotis (*Myotis volans*) range across western North America from the western Northwest Territories to Mexico (Warner and Czaplewski 1984, Lausen *et al.* 2014). The northern extent of their range in western Canada appears to follow montane and coastal forests, but they are more widely distributed in arid region of the south (Nagorsen and Brigham 1993). The species is common along the Rocky Mountains and in the Milk River area in southern Alberta (Schowalter 1979, 1980, Saunders and Barclay 1992, Lausen 2004). However, records north of the Milk River are sporadic, and their range is poorly delineated across most of the prairies (Alberta Environment and Parks 2016). Previous records in Alberta indicated they occur as far north as Driedmeat Lake near Camrose (Soper 1964); however, this was based on a museum collection later determined to be a Little Brown Myotis (Schowalter pers. comm.).

White-nose syndrome is not currently within the range of Long-legged Myotis, so little is known regarding their susceptibility. However, they frequently roost and hibernate with Little Brown Myotis in Alberta (Schowalter 1980, Saunders 1989), suggesting their risk of exposure may be similar. Fatalities at wind energy facilities in Alberta and elsewhere in North America is currently low (Baerwald and Barclay 2011, Arnett and Baerwald 2013), but could become a greater issue if development were to occur in areas where Long-legged Myotis were more common.

Basic aspects of the ecology of Long-legged Myotis in Alberta are poorly understood, which impedes the development of appropriate conservation measures. They occur in large numbers in the Milk River badlands, and are likely sensitive to disturbance and habitat loss in this area. In particular, they commonly forage around cottonwood (Saunders and Barclay 1992), and may be adversely affected by the loss of riparian forests. They are known to use buildings as maternity colonies in Alberta, so could be adversely affected by human disturbance, eviction, extermination, or accidental entrapment. Only two hibernacula – representing a negligible number of individuals – have been discovered in the province (Schowalter 1980). The location of most hibernacula are unknown, making effective protection measures difficult to implement.

9.2 Ecology

Long-legged Myotis are assumed to be year-round residents, undergoing short-distance migrations within the province between summer and winter habitat. Few studies have reported the timing of life-history events within the province, but the species appears to have similar timing to Little Brown Myotis, which share similar habitat. Female Long-legged Myotis arrive at maternity colonies already pregnant shortly after emerging from hibernation, which occurs from about April to mid-May (Schowalter *et al.* 1979). A building maternity colony in Jasper was colonized by about the middle of April (Horne pers. comm.). The timing of reproduction is likely similar to Little Brown Myotis, which depending on conditions, give birth from about mid-June to late-July in southern Alberta (Coleman and Barclay 2011). Typically a single pup is born per year (Barclay 1993). Juveniles likely fledge around early-July to mid/late-August. Pups were evident in a mixed Long-legged Myotis and Little Brown Myotis colony in the Milk River valley beginning July 6th, but could not be identified to species (Saunders 1989). Juveniles in the Milk River area were also found roosting apart from their mothers around the end of July or early August (Saunders pers. comm.), suggesting they were born by early July. However, reproductive timing in Long-legged Myotis appears to be highly variable, and may occur later than this period, especially during poor years (Druecker 1972).

In the mountains, Long-legged Myotis start congregating (swarming) at hibernacula about mid-August, and begin hibernating in large numbers around the end of September (Schowalter 1980). Breeding is polygynous and occurs during the fall and winter, and includes first-year juvenile males (Schowalter 1980). Males commonly emerge from hibernation to mate with torpid females, but mating also occurs prior to hibernation during the fall swarming period. Pregnancy is delayed until females emerge from hibernation in the spring (Druecker 1972).

9.2.1 Diet

Long-legged Myotis are moth specialists, with Lepidoptera (moths) consistently the dominant dietary component (Black 1974, Whitaker Jr *et al.* 1977, Warner 1985, Saunders and Barclay 1992, Johnson *et al.* 2007, Ober and Hayes 2008). Lepidoptera comprised approximately 71% of the diet of Long-legged Myotis along the Milk River in Alberta, with most of the remainder divided between Coleoptera (beetles) and Diptera (midges) (Saunders and Barclay 1992). Coleoptera was a major component, in addition to Lepidoptera, of the diet for a study in Idaho (Johnson *et al.* 2007); however, this may have been the result of local insect availability because most other studies report much lower levels of Coleoptera. Most studies report prey from a variety of insect orders, as well as spiders, indicating the species will opportunistically forage on prey other than moths.

9.3 Habitat Requirements

9.3.1 General

There is a generally poor understanding of the foraging and roosting ecology of Long-legged Myotis in Alberta. Although some work has been completed to document their presence and basic use of foraging habitat in the Milk River area in southern Alberta, additional research is needed throughout the province to better understand even basic aspects of their ecology, such as distribution and habitat use. Like all bats, they require access to food, shelter, and water. On the prairies, these resources are likely most available along prairie river valleys (Holloway and Barclay 2000), especially in the vicinity of the Milk River. However, they are rare along the Red Deer, Bow, and South Saskatchewan rivers east of the foothills, suggesting that important habitat elements may be missing from these areas (Holloway 1998, Lausen 2006).

9.3.2 Foraging Habitat

A variety of foraging habitats are used by Long-legged Myotis across their range, but few habitat associations can be generalized (Johnson *et al.* 2007). Instead, the Long-legged Myotis, which is commonly considered to be a moth specialist, may select habitats based on the distribution of moths (Saunders and Barclay 1992, Johnson *et al.* 2007). They are well adapted to slow maneuverable flight; however, this appears to be more an adaptation for capturing moths and other prey, as they do not appear to commonly forage in cluttered habitat where maneuverable flight would be imperative (Saunders and Barclay 1992).

Prairie populations of Long-legged Myotis are known primarily from the Milk River area, where they are known to forage in the river valley and adjacent coulees. In this area, foraging was observed to occur primarily in the open, and often high above the ground and along the edges of sandstone cliffs (Saunders and Barclay 1992). Foraging for aquatic insects near the surface of the water appears to be much less common than observed for Little Brown Myotis in the same area. Instead, they spend a greater proportion of their time foraging away from aquatic habitats, along dry coulees and around trees and shrubs. Schowalter (1978) captured two Long-legged Myotis below a yard light near the Milk River, suggesting they may forage on moths attracted to lights. Foraging under yard or street lights appears to be a common behaviour among moth specialists (Hickey *et al.* 1996).

9.3.3 Roosting Habitat

The few available roost reports of Long-legged Myotis in Alberta indicate they roost in buildings and rock crevices in the province (Schowalter 1979, Saunders 1989). The use of rock crevice roosts is consistent with observations in other parts of their range (Ormsbee and McComb 1998, Cryan *et al.* 2001, Baker and Lacki 2006). Building roosts have also previously been reported outside of Alberta (Dalquest and Ramage 1946, Davis and Barbour 1970), but a relative scarcity of reported observations in buildings suggests these are not the most common roost structure in at least some regions. However, Long-legged Myotis has a tendency to roost in mixed groups with the more abundant Little Brown Myotis (Davis and Barbour 1970, Saunders 1989), possibly resulting in their use of building roosts being under-reported.

All reports of roost use by Long-legged Myotis in Alberta have been of incidental findings, and no studies have been designed to evaluate the potential use of tree roosts. However, across other parts of their range, snags and decaying living trees are often the mostly frequently used roosting structure (Ormsbee and McComb 1998, Rabe *et al.* 1998, Herder *et al.* 2000, Cryan *et al.* 2001, Baker and Lacki 2006, Arnett and Hayes 2009, Lacki *et al.* 2010). Older forests where trees have begun to decay are most likely to have suitable roost trees for cavity-roosting bats (Crampton and Barclay 1998). Large numbers of Long-legged Myotis occur along the Milk River, where they commonly forage among western cottonwood (*Populus deltoides*) (Saunders and Barclay 1992). Cottonwood appear to have suitable characteristics for roosting; however, other studies in riparian badlands have found rock crevice roosts to be more commonly used by prairie bats even when cottonwood are present (Holloway 1998, Lausen 2007). The only reported roosts along the Milk River consists of a large rock crevice roost and a temporary roost under a sign attached to a building (Saunders 1989, Saunders pers. comm.).

Concrete bridges – especially those over streams in forested habitats – are known to be frequently used as night roosts in Oregon (Perlmeter 1995, Ormsbee 1996). Females at these night roosts often roost in groups, up to several kilometers from day roosts, and not necessarily with the same individuals they roost with during the day (Perlmeter 1995). Presumably, high quality night roosts mediate social behaviours in this species and may provide important benefits (e.g., energy savings). Because night roosts are typically near foraging habitat, the availability of night roosts has been suggested as a possible factor affecting use of foraging habitat (Perlmeter 1995). Additional night roost structures are likely used, possibly including similar structures to what is used during the day as observed in other prairie species (Holloway 1998).

9.3.4 Maternity Roosts

Most records of maternity roosts in Alberta are of incidental reports of colonies in buildings. In Alberta, multiple building roosts have been reported in the Rocky Mountains and adjacent foothills, including Waterton (Schowalter 1979), Jasper (Greg Horne pers. comm.), and Beaver Mines (Baerwald, E. pers. comm.). A maternity roost in Jasper was located in the attic of a two-story log building, and consisted of approximately 95 individuals (Horne pers. comm.). A colony of Long-legged Myotis was also found to be sharing a barn with Little Brown Myotis in Beaver Mines (Baerwald, E. pers. comm.). The Beaver Mines roost was an old wooden barn that was retrofitted with metal siding and roofing. Both species roosted between the metal siding and the original wood siding, although not necessarily in the same location of the building.

In the Milk River valley, Saunders (1989) found a maternity colony of Little Brown Myotis and Long-legged Myotis roosting in a crevice along a south-facing sandstone cliff (Figure 7). Both species were observed roosting together in a tight cluster and intermixing of species regularly occurred. The colony was estimated to consist of 94 adult females and their pups, but only banded bats could be identified to species – at least four of each species could be confirmed occupying the roost. This is a much greater number of individuals than has been reported for rock-roosting colonies in South Dakota, where the average group size was 3.6 individuals (range 1 to 31; Cryan *et al.* 2001).

The roost in the Milk River valley consisted of a slab of rock 1.1 m wide and 0.75 m tall, which was situated about 2.1 m above the ground (Saunders 1989). A narrow crevice (approximately 4 cm wide) ran along one side of the roost and along the bottom, which allowed access by bats. The cliff face was sheltered by nearby cottonwood. Interestingly, bats occupied the roost consistently for at least a 20-day period beginning June 29, spanning from the time when the roost was first found to when it was abandoned due to disturbance by a park visitor. This period is much longer than reported for other rock-roosting bats in prairie badlands (Lausen 2007, Nixon *et al.* 2009). An additional roost was found near the Milk River that was located under a family sign attached to the south side of a wooden house (Saunders pers. comm.). The roost was only used temporarily during late July/early August and consisted of a mixed group of about 21 juvenile Long-legged Myotis and Little Brown Myotis.

Although not confirmed in Alberta, tall, large diameter snags and decaying living trees, with exfoliating bark, are the most common maternity roost structures in many parts of their range (Ormsbee and McComb 1998, Rabe *et al.* 1998, Herder *et al.* 2000, Cryan *et al.* 2001, Baker and Lacki 2006, Arnett and Hayes 2009, Lacki *et al.* 2010). Roosts in trees are typically under sloughing bark, as well as internal tree cavities (Vonhof and Barclay 1996, Ormsbee and McComb 1998, Lacki *et al.* 2013). Average roost-tree diameters across studies range from approximately 43 cm (Cryan *et al.* 2001) to 100 cm (Ormsbee and McComb 1998), and average height ranges from approximately 11 m (Cryan *et al.* 2001) to 40 m (Ormsbee and McComb 1998). Trees with diameters as small as 25 cm were still used by Long-legged Myotis in British Columbia (Psyllakis and Brigham 2006), although not necessarily as maternity colonies. Larger maternity groups (i.e., ≥ 50 individuals) are typically found in taller, larger diameter snags than those used by smaller maternity groups (Baker and Lacki 2006). Large hollowed trees, in particular, have been observed to support maternity colonies in excess of 300 individuals, and may be important resources for the species (Ormsbee and McComb 1998).

Most studies only report coniferous species being used as roosts, including Ponderosa Pine (*Pinus ponderosa*), Grand Fir (*Abies grandis*), White Fir (*Abies concolor*), Douglas Fir (*Pseudotsuga menziesii*), Western White Pine (*Pinus monticola*), Western Redcedar (*Thuja plicata*), Western Larch (*Larix occidentalis*), and Western Hemlock (*Tsuga heterophylla)* (Ormsbee and McComb 1998, Arnett and Hayes 2009, Lacki *et al.* 2013). However, two roosts in deciduous species (*Populus sp*.) were reported in British Columbia (Psyllakis and Brigham 2006). Roost selection appears to change in response to changing physiological requirements. For example, lactating individuals in the northwestern United States were more likely to select thick-barked snags during lactation than during pregnancy, presumably because these snags provided greater thermal insulation to protect vulnerable pups (Baker and Lacki 2006). Snags appear most likely to be selected if they are in areas with a high density of other snags (Rabe *et al.* 1998, Herder *et al.* 2000, Arnett and Hayes 2009).

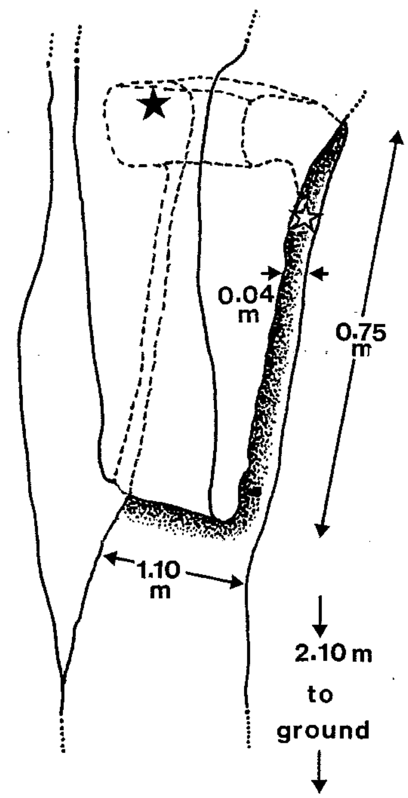

Figure 7. Diagram of a rock crevice roost used by Long-legged Myotis and Little Brown Myotis along the Milk River in southern Alberta. Approximately 95 adults were estimated to use this roost. Roosting occurred under a rock slab that partially separated from a south facing sandstone cliff. Dashed lines represent the space between the cliff and the rock slab. The open star represents the level at which the two species were observed to roost. The closed star indicates where bats were suspected to roost, but which could not be directly observed. Diagram reprinted, with permission, from Saunders (1989), unpublished manuscript.

9.3.5 Hibernacula

Caves and mines are the most commonly reported hibernacula used by Long-legged Myotis throughout their range (Schowalter 1980, Hendricks 2012). In Alberta, Long-legged Myotis are known to hibernate in Cadomin Cave (near Hinton) and Wapiabi Cave (in Nordegg) (Schowalter 1980). However, all hibernacula in Alberta combined can only account for a few thousand bats of any species, which is a very small proportion of the overall bat population in the province (Olson *et al.* 2011). Deep rock crevices could also be used for hibernation, especially along the Milk River valley, but this behaviour has not been documented in Alberta.

9.3.6 Area Requirements

Specific information on the home range requirements are not available for northern populations of Long-legged Myotis. However, in Idaho, the average home range size (excluding the outer 5% of observations) ranged from 304 ha (for lactating females) to 647 ha (for males) (Johnson *et al.* 2007). However, core area (i.e., the area over which 50% of observation occur) was much smaller, ranging from 52 ha (for lactating females) to 103 ha (for males). Home ranges of males were much more variable than females (ranging from 17 to 3,029 ha), but were not significantly different.

Additional information is available from radio-telemetry studies that report average distances from capture locations to roosting locations. This information can be used to infer the minimum foraging distances of bats, because bats are usually captured while foraging or commuting. These distances averaged 1.9 km (range 0.4 to 3.7 km) for bats in South Dakota (Cryan *et al.* 2001) and 3.2 km (range 0.2 to 7.9 km) for bats in Arizona (Herder *et al.* 2000). At least 5 bats in Arizona foraged more than 10 km from roosts. A male and female Long-legged Myotis in British Columbia roosted 0.1 km and 3.0 km from its capture location, respectively (Vonhof and Barclay 1996).

Like other bat species that roost in tree cavities and under bark, Long-legged Myotis switch roosts frequently throughout the summer. Across their range, average roost switching frequency for mostly tree roosting individuals ranges from about 2 to 4 days (Herder *et al.* 2000, Cryan *et al.* 2001, Baker and Lacki 2006). Although individual roosts may only be used for short durations, some Myotis bats show high fidelity to well defined roosting areas (Lausen 2007, Olson and Barclay 2013). Although the size of typical roost areas is unknown, reported distances between successive roosts suggest these areas may be large. Individuals in the northwestern United States – mostly tree-roosting females – moved an average of 1.4 km between successive roosts (Baker and Lacki 2006). Individuals in South Dakota – mostly rock-roosting females – moved an average of 0.7 km (range 0.2 to 1.6 km) between successive roosts (Cryan *et al.* 2001). A single male and female in British Columbia moved an average of 0.21 km and 0.03 km, respectively, between consecutive roosts (Vonhof and Barclay 1996). The distance between multiple roosts in Oregon averaged approximately 0.4 km for most bats, but averaged 3.7 km for one individual (Ormsbee 1996). The same study in Oregon found the distance between day roosts and night roosts – which are typically located near foraging habitat – averaged 2.5 km (range 0.7 km to 6.5 km).

10 WESTERN SMALL-FOOTED MYOTIS

10.1 Background

Western Small-footed Myotis (*Myotis ciliolabrum*) is the smallest bat in Alberta, with non-pregnant females weighing approximately 5.4 g (Lausen 2007). They occur in primarily arid and semi-arid regions of western North America from southwestern Canada to Mexico (Holloway and Barclay 2001). Two subspecies have been recognized: *M. c. ciliolabrum* is found in Alberta, Saskatchewan, Montana and a few other states of the northern Great Plains, whereas *M. c. melanorhinus* is found in British Columbia, and most of the rest of southwestern North America (Holloway and Barclay 2001). Their range in Alberta is highly restricted, primarily occurring in badland habitat along the Red Deer, South Saskatchewan, and Milk rivers (Lausen and Schowalter 2008). Individuals seldom move between river systems, which limits gene flow, and effectively makes three distinct subpopulations in Alberta. These groups are further separated from subpopulations farther south in Montana (Lausen 2007). Their narrow geographic range in Alberta and high habitat specificity has resulted in their listing as a Species of Special Concern under the Alberta Wildlife Act (Government of Alberta 2014).

Riparian cottonwood stands are believed to be particularly important for Western Small-footed Myotis in Alberta, especially for use as foraging habitat (Holloway and Barclay 2000). However, roosting appears to primarily occur in rock crevices and erosion holes (Holloway 1998, Lausen 2007). Disturbance, degradation, and loss of riparian cottonwood stands and adjacent rock formations is an important conservation concern for this species (Lausen and Schowalter 2008). Dams and river diversion projects are a particular concern, because of both potential flooding of riparian habitats upstream of dams, as well as the downstream attenuation of flood cycles. Flooding creates conditions suitable for cottonwood seed establishment and clonal propagation, so the attenuation of flood cycles is likely to reduce the recruitment of new trees. Reduced seed establishment is made worse by the cumulative effect of improper grazing pressure within riparian systems, further depleting the number of cottonwood that reach maturity (Samuelson and Rood 2004).

10.1.1 Ecology

Females give birth from about late June to late July in Alberta, but the exact timing depends on local environmental conditions (Holloway 1998, Lausen 2007). Typically, only one pup (or occasionally twins) is born per year (Holloway and Barclay 2001), and likely not until their second or third year. Young begin foraging on their own around mid July to late August (Holloway 1998). Males produce sperm throughout the summer and store it until mating, which occurs during the fall and possibly winter. Mating is polygynous, and to avoid inbreeding, presumably coincides with dispersal of males and/or females during the fall. Pregnancy is delayed until the following spring (Lausen and Schowalter 2008). Hibernation is poorly understood, but likely occurs sometime from about September to April, similar to other prairie bat species. Males and females return to their natal home ranges following hibernation.

10.1.2 Diet

Western Small-footed Myotis has a diverse diet of small-bodied nocturnal flying insects. Diets vary by season, and likely regionally, depending on local insect availability. One study in Alberta, along the South Saskatchewan River, found the majority of their diet consisted of Diptera (true flies) and Lepidoptera (moths). These two insect orders represented about three quarters of the diet (Holloway 1998). Most of the remaining diet consisted of Coleoptera (beetles). Diptera was the most common prey during the early summer (May and June) while Lepidoptera was the most common prey during the late summer (July and August). Coleoptera was a substantial component of the diet primarily during the early summer, when it comprised approximately a quarter of the diet. The dipteran component was heavily dominated by the combined Culicidae (mosquitoes) / Chaoboridae (phantom midges) group.

Another study in southern Alberta found Lepidoptera to be the most common prey species, followed by lower amounts of Diptera and Coleoptera (Shima 1996, as cited in Holloway 1998). In that study, Hemiptera (true bugs), Hymenoptera (bees and ants), and Neuroptera (net-winged insects) were a much more prominent component of the diet. The frequency of Lepidoptera, along with lower amounts of Coleoptera, Diptera, Hemiptera, Hymenoptera and Neuroptera has also be found in more southern portions of their North American range (Warner 1985).

10.2 Habitat Requirements

10.2.1 General

Western Small-footed Myotis occurs in rugged badlands along the Red Deer River, South Saskatchewan River, and Milk River (Lausen and Schowalter 2008). Within this area, bats require suitable foraging and roosting habitat, as well as a source of water for drinking. Close proximity between roosts and open water for drinking may be particularly important due to the species' small size and tendency to occupy arid environments (Adams and Thibault 2006).

Little is known about Western Small-footed Myotis in Alberta outside of the breeding season. However, winter activity is known to occur along the Red Deer River, indicating the presence of nearby hibernacula (Lausen and Barclay 2006*b*). Furthermore, markedly little gene flow occurs between river systems, suggesting males and females stay within the same river system to mate (Lausen 2007). This implies that rearing offspring, mating and hibernation may all occur along the same river system, which is a level of specificity not known to occur for other Alberta bats (Lausen and Schowalter 2008). Some gene flow still occurs between river systems, but is concentrated in areas where corridors – such as stream banks or long coulees – connect the two drainages (Lausen 2007, Lausen and Schowalter 2008). These corridors may be especially important for mediating gene flow among adjacent river systems.

10.2.2 Foraging Habitat

Foraging habitat in Alberta occurs along riparian corridors of the Red Deer, South Saskatchewan, and Milk River. Springs and cottonwood patches within riparian areas are especially important foraging habitat (Holloway and Barclay 2000, Lausen 2003). However, some foraging also occurs near coulees and along treeless portions of the river. Along the South Saskatchewan River, most foraging occurs within 1 km of the river, which contains most of the coulees, springs, and cottonwood patches where foraging occurs (Holloway and Barclay 2000). Open prairie habitat farther than 1 km from the river generally has little or no foraging activity.

10.2.3 Roosting Habitat

The Western Small-footed Myotis primarily roosts in rock crevices throughout its range (Holloway and Barclay 2001). In Alberta, suitable roosting habitat occurs in steep rugged terrain of the South Saskatchewan, Red Deer, and Milk River valleys, where eroded sedimentary rock and mudstone creates cavities suitable for roosting (Holloway 1998, Lausen 2007). Roosts under sloughing bark, buildings, and bridges have been documented in other parts of their range, but does not appear to be commonly used in Alberta (Holloway and Barclay 2001). The species shows long term fidelity to specific roosting patches, and related individuals are more likely to occupy the same roosting area (Lausen 2007). Night roosts include the same roosts as used during the day, but may also include other structures, such as small caves (Holloway 1998).

10.2.4 Maternity Roosts

Studies of maternity roosts in Alberta are primarily from the South Saskatchewan and Red Deer river valleys. In these regions, bats roost most often in mudstone erosion holes (Figures 8 and 9). However, a variety of other rock crevices may also be used, such as slabs of rock broken away from larger boulders (Figure 1), boulder cracks, rock/mud combinations, shelters created by overhanging rock, and crevices along cliff faces (Holloway 1998, Lausen 2003, 2007). Roost selection appears to be similar between the pregnancy and lactation period (Lausen 2007). Southern aspects are most common, but may occur on either side of the river (Lausen 2003, 2007). Crevices or cavities used as roosts generally have narrow entrances, likely to prevent access by predators, and are typically shallow enough to allow passive warming of the roost by the sun (Holloway 1998, Lausen 2007). Roosting may occur along steep terrain, as well as on relatively level ground (Holloway 1998, Lausen 2007).

Reproductive females roost either alone or in small matrilineal family groups, which typically consist of 2 to 35 bats, with 2 to 5 more common (Lausen 2007). Frequent roost switching is common, but occurs within a small < 110 m section of the valley (Holloway 1998, Lausen 2007). Females typically move roosts daily (Lausen 2007), but some roosts may be reused over several days (e.g., ≥ 6 days) (Holloway 1998).

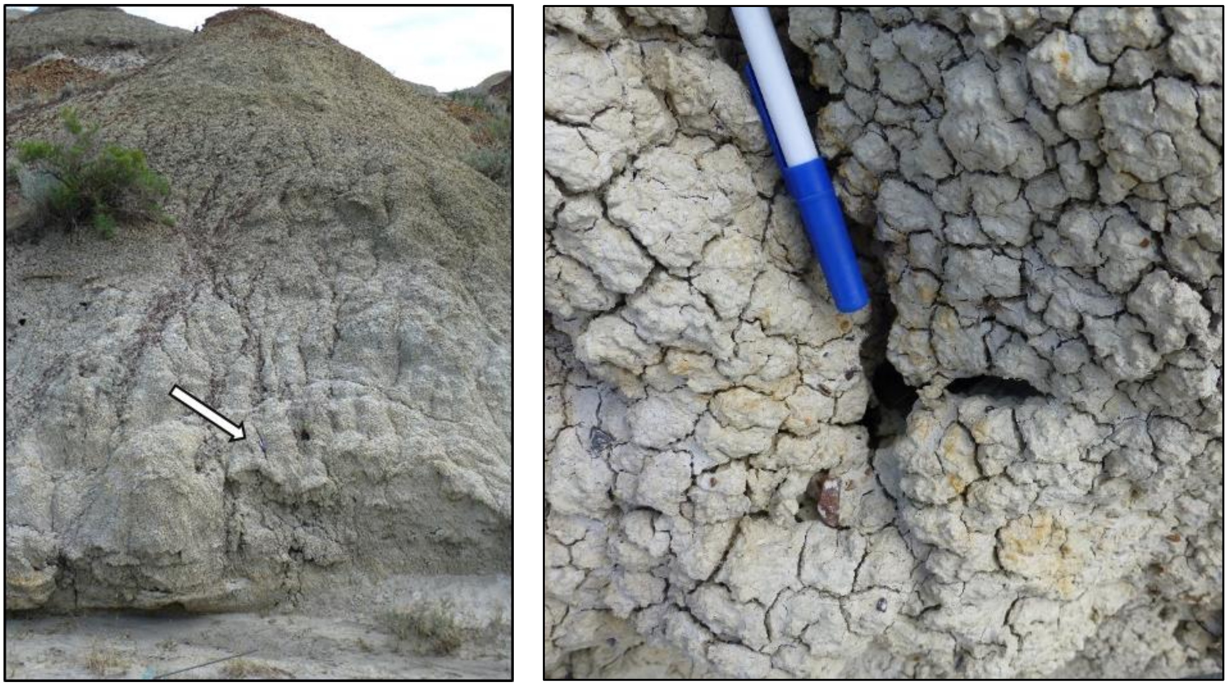

Figure 8. Wide angle and close up view of a typical erosion cavity used by Western Small-footed Myotis in the Red Deer River valley. The arrow / pen points to the roost entrance. Photos courtesy of Stephanie Findlay.

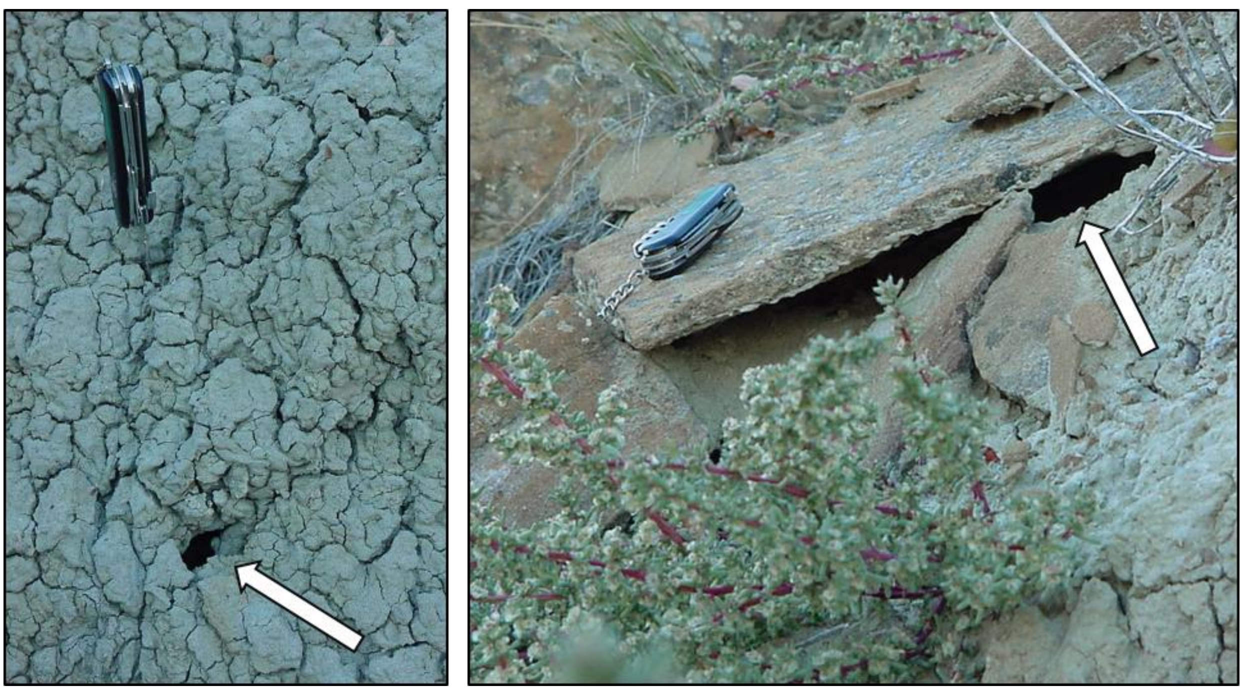

Figure 9. Roosts typical of those used by Western Small-footed Myotis in the South Saskatchewan River valley. In the left photo, roosting occurred in an erosion hole that developed in solidified mud. In the right photo, roosting occurred between a rock slab and solidified mud. Photos courtesy of Cori Lausen.

10.2.5 Hibernacula

Winter activity has been observed in the badlands along the Red Deer River valley, and they may hibernate in deep rock crevices similar to Big Brown Bats (Lausen and Barclay 2006*b*). The species roosts throughout the summer in rock crevices and erosion holes along river valleys, so hibernacula may be in similar locations to their summer breeding habitat (Lausen and Schowalter 2008). However, additional studies are needed to document the use of winter hibernacula.

10.2.6 Area Requirements

Home ranges of the Western Small-footed Myotis appear to be small in Alberta, rarely extending beyond the river valley or adjacent coulees where they occur (Holloway 1998, Lausen 2007). Bats roosted an average of 146 m (range 4 to 580 m) from their capture location along the South Saskatchewan River (Lausen 2007), which suggests that bats are foraging in the general vicinity of their roosts. Foraging by a small number of radio tagged bats was restricted to within 2 km of their roost, further supporting evidence of small home ranges (Lausen 2003). Small home ranges may be facilitated by the close proximity of rock/mudstone crevices used for roosting and cottonwood stands used for foraging, which is common in the prairie river valleys in Alberta where they occur. In other areas of their North American range, commuting distance of up to 12 km has been reported, suggesting longer-distance commutes can be accommodated (Rodhouse and Hyde 2014).

Roosting areas for the species are exceptionally small. Individual bats along the South Saskatchewan River typically roosted within a < 110 m section of the river valley or adjacent coulees (Lausen 2007). This roost area corresponded to an average distance between successive roosts of 45 m (range 6.4 to 106 m). Genetic analysis has shown that each roosting area consists of one family unit, related along the female lineage (Lausen 2007). Both adult males and females appear to return to their natal roosting area (Lausen 2007). This results in a mosaic of roosting ranges where each matrilineal family of multiple generations roosts in the same ~110 m section of the river valley (Lausen pers. comm.). Therefore, localized destruction of relatively small sections of individual coulees or other riparian habitat, such as through development or flooding, has potential to result in the loss of whole female lineages (Lausen and Schowalter 2008).

Winter activity by Western Small-Footed Bats in prairie river valleys suggests that at least some individuals may hibernate in the same type of habitat as used during the summer (Lausen and Barclay 2006*b*). However, some degree of dispersal apparently occurs prior to mating to prevent inbreeding and facilitate gene flow within the population. Genetic patterns within and among populations suggests that mating primarily occurs among clusters of individuals along the same river valley, but may still involve movements of up to approximately 150 km (Lausen and Schowalter 2008). Mating between river valleys also occurs, and is mediated by habitat corridors that connect different drainages (Lausen 2007).

11 GRAZING AND PRAIRIE BATS

11.1 Background

There are few comprehensive studies of the effects of grazing on bats, especially in Alberta, but several outcomes can be predicted based on how grazing effects habitats used by bats or their insect prey. However, these mechanisms are usually indirect and difficult to observe, which limits assessments of their importance for bat conservation (Chung-MacCoubrey 1996). This is especially true given that limiting (or critical) habitat for bats is difficult to evaluate: any combination of roosting, foraging, migration, overwinter, and water resources may be limiting, depending on the area and species.

As aerial insectivores, bats do not directly rely on grass cover in the same way observed for many grassland birds. In most circumstances, direct disturbance by livestock is unlikely because most bats hide within concealed cavities in trees, rock crevices or buildings that are either inaccessible or in locations that livestock generally avoid. Roosts of Western Small-footed Myotis and Long-eared Myotis often occur in erosion cavities or amongst rock piles that are located near or below the ground on relatively flat surfaces (Lausen 2007, Nixon *et al.* 2009). These roosts may be accessible to livestock and could be susceptible to disturbance or damage, but more typically occur in areas of sparse vegetation or in rugged terrain that livestock usually avoid (Lausen pers. comm., Barclay pers. comm.).

The primary effect of grazing is likely through changes in the availability and quality of roosting and foraging habitat, and associated changes in prey communities. Substantial amounts of anecdotal evidence also suggests that poorly designed fences and water troughs associated with grazing may be contributing to high levels of bat mortality (Long 1964, Wisely 1978, Taylor and Tuttle 2007). Although more studies are needed to evaluate the effect of grazing on bats, the following factors should be considered when designing grazing management plans:

- **Foraging and roosting habitat:** Bats use a diversity of foraging and roosting habitats throughout the year, and these are most likely to be found in heterogeneous natural landscapes. Intensive grazing, conversion to improved pasture, or land improvement activities (e.g., building roads, removal of woody debris, trees, or rock piles) are likely to result in the loss of foraging and/or roosting habitat required by bats. Of particular concern is the effect of grazing on riparian cottonwood recruitment. Heavy grazing pressure has been implicated in contributing to the loss or degradation of riparian cottonwood forest on the prairies. Proper grazing management can prevent these negative impacts.
- **Prey availability:** Intensive grazing and conversion to tame pasture may reduce the diversity and abundance of insect prey as a result of the loss of vegetation biomass and/or homogenization of the structure and composition of vegetation or landscape features. Likewise, grazing of wetlands may reduce water quality and the availability of aquatic

vegetation, which reduces the abundance and/or diversity of aquatic insects preyed on by bats.

- **Water sources and incidental mortality:** Artificial water sources can be important resources for bats and may attract bats to new areas. However, substantial numbers of bats may drown in water troughs, tanks, and other receptacles if appropriate escape structures are not installed. This issue is made worse if obstacles (e.g., fencing) are placed above the water. Entanglement on barbed wire fences may also be a concern, especially near wetlands and other sources of water where bats are likely to be flying low.

Many concerns can be mitigated through the application of appropriate management practices, such as access restrictions, low-intensity grazing systems, and designing bat friendly water sources. If properly managed, grazing may benefit bats, such as by attracting insect prey (e.g., dung beetles) or by increasing structural complexity of rangeland vegetation. Artificial water sources (e.g., troughs, dugouts) installed to support grazing cattle may also be a major benefit to bats provided they are designed to prevent entrapment and drowning (Chung-MacCoubrey 1996). Grazing may also be a good alternative to more intensive land uses that are less compatible with bat conservation, such as cultivated fields.

The following sections describe potential effects of grazing in greater detail.

11.2 Effects of Grazing on Foraging and Roosting Habitat

Several studies have noted the importance of landscape heterogeneity for the conservation of bats. Retention of greater amounts of trees in agricultural landscapes is particularly important, and is frequently associated with greater bat activity and species richness. Various studies have found higher bat activity around scattered trees, tree groves, linear hedgerows, and riparian woodlands (Holloway and Barclay 2000, Lumsden and Bennett 2005, Boughey *et al.* 2011, Lentini *et al.* 2012, Heim *et al.* 2015, Kalda *et al.* 2015). Native pasture with retained trees, downed logs, rock debris, and other hollows are likely to support greater bat diversity and activity than improved pasture (Lentini *et al.* 2012).

Cottonwood forests are the primary – or possibly only – roosting habitat for tree bats in otherwise open prairie landscapes, and represents important foraging habitat for prairie bats (Holloway and Barclay 2000). Riparian zones with cottonwood have been found to have several times the level of bat activity than riparian habitat where trees do not occur (Holloway and Barclay 2000, Swystun *et al.* 2007). Trampling and browsing of tree saplings by cattle can prevent regeneration of cottonwood forests, resulting in the loss of forested habitat or a homogeneous age distribution of old decaying-trees (Rood and Mahoney 1990, Samuelson and Rood 2004). This effect is worsened by the cumulative effect of attenuated flood cycles resulting from the damming of rivers, which further reduces establishment of new cottonwood (Rood and Mahoney 1990).

The homogenization of the age structure of cottonwood stands is a particular concern for the conservation of tree-roosting bats. These bats typically alternate among many roosts within an area, and individual roosts may only be used for a few days at a time. However, bats are long-lived, and colonies may reuse the same roosting area over years or decades (Willis and Brigham 2004). For the long-term persistence of bats in an area, there must be regular replacement of roosts as they decay and become unsuitable for roosting, which requires a diverse forest-age structure (Swystun *et al.* 2007, Lacki *et al.* 2012). Most bats roost in old, tall or decaying trees, which are typically at least a few decades old. As a result, the loss of cottonwood recruitment will not affect bat roosting habitat for many years, but will have long-lasting repercussions once the remaining trees decay and fall over. Cottonwood forests managed to ensure the regular establishment of new seedlings will provide important benefits for bat conservation.

11.3 Effects of Grazing on Prey Availability

At least some bats appear to preferentially forage in the vicinity of cattle, likely because they attract flying insects or disturb insects from the ground as they move. Pastures with cattle have been associated with significantly greater bat activity than pastures where cattle have been recently excluded (Downs and Sanderson 2010). Big Brown Bats, in particular, may forage on dung beetles that are sustained by cattle feces in grazed pastures (Arbuthnott and Brigham 2007). However, while cattle may create habitat niches for insects consumed by bats, they also deplete the biomass of vegetation needed to support diverse and abundant insect communities.

Grazing intensity has a strong influence on arthropod diversity and abundance (van Klink *et al.* 2015), and therefore has potential to influence the distribution and availability of prey taken by bats. Intensive grazing results in high direct mortality of arthropods, and depletion of vegetation biomass needed to support an abundant and diverse arthropod community (van Klink *et al.* 2015). Depletion of vegetation also simplifies vegetation structure and leads to further declines of arthropods through the elimination of habitat niches exploited by different arthropod species (Dennis *et al.* 1998). As a result, many studies find an overall reduction in arthropods in grazed landscapes (van Klink *et al.* 2015). However, properly managed grazing has potential to increase structural and microclimatic heterogeneity of rangeland vegetation. Low intensity grazing may be beneficial to arthropods by allowing periods of recovery, while still maintaining diverse, structurally complex rangelands.

Intensive grazing of wetlands has potential to negatively affect aquatic insect diversity, primarily through the destruction of emergent vegetation, and possibly through the reduction in water quality (Hornung and Rice 2003, Lee Foote and Rice Hornung 2005). Reduced diversity of aquatic insects is likely to decrease dietary diversity for bats which forage in aquatic habitats, including the Endangered Little Brown Myotis (Clare *et al.* 2011). Bats are known to shift prey species within and among nights, in response to variation in abundance and the timing of insect activity (Rolseth *et al.* 1994, Hamilton and Barclay 1998, Clare *et al.* 2014*a*). Therefore, reduced insect diversity may be detrimental by reducing the number of alternative prey species and increasing temporal variation in prey availability. Reduced macroinvertebrate diversity may also disproportionately affect certain bats species specializing on large-bodied insects at higher trophic levels. For example, some Hoary Bats forage extensively on dragonflies (Odonata) (Rolseth *et al.* 1994), which are known to be sensitive to cattle grazing in aquatic habitats (Lee Foote and Rice Hornung 2005).

11.4 Water Sources and Incidental Mortality

Bats have high water demands and artificial sources of water have potential to provide tremendous benefits to bats, especially in arid prairie environments where many natural wetlands are no longer available. However, there have been many anecdotal observations of bats becoming trapped and drowning while attempting to drink from water troughs, tanks, rain barrels, pails, and other artificial sources of open water that lack appropriate escape options (Taylor and Tuttle 2007). Although quantifying the importance of this source of mortality is difficult, it appears to be frequent and widespread in many agricultural communities, and potentially represents a major source of mortality.

Bats typically drink by skimming the surface of calm open water while in flight. Water troughs and other receptacles are often attractive to bats, but frequently have obstructions that increase the risk of collisions and entrapment (Taylor and Tuttle 2007). Although bats can swim, they typically cannot become airborne unless they reach a few meters' height above unobstructed airspace. The steep, smooth sides typical of water vessels do not permit bats to climb out, resulting in their eventual drowning. Drowning bats are likely to emit distress calls, which will attract other bats and may lead to high levels of mortality. For example, a single tire trough in Texas killed 46 bats in one incident (Taylor and Tuttle 2007). Likewise, in the Yukon, a pail of water left in a cabin killed 53 Little Brown Myotis, which likely fell in after hitting a trip wire above the pail (Jung and Slough 2005). Drowned animals will degrade water quality and reduce its suitability for livestock, making wildlife friendly designs good practice for both wildlife and livestock management.

Obstructions such as bracing and wires above the water increases the risk of collisions and drowning (Taylor and Tuttle 2007). Particularly problematic are water troughs placed along fence lines to allow simultaneous access by cattle from different pastures. In these cases, the fences are often placed directly above the water, which increases the risk of collisions and subsequent drowning. Tire troughs, made from old tractor tires, appear to be especially risky for bats because the recessed sides prevent escape. Low water levels also increase the risk to bats. This is because the added height of the sides of the vessel above the surface of the water prevents bats from escaping, and the sides are more difficult for bats to avoid while they are skimming the surface of the water to drink. Even if no mortality occurs, a sudden depletion of an artificial water source used by bats – such as if the water is turned off after cattle are moved – may be disruptive to bats that rely on that water source.

Another risk to bats associated with grazing is entanglement on barbed wire. Bats have thin wing and tail membranes required for flight that are susceptible to tearing. Although the importance of this risk is poorly understood, some bat species appear susceptible to entangling their wing and tail membranes on barbed wire (Long 1964, Wisely 1978). Less maneuverable species that are adapted to fast open-air flight, such as the Hoary Bat, appear more susceptible to this issue. This risk is likely greatest near water, because bats fly low to drink and to forage on aquatic insects flying near the surface.

12 GRAZING SYSTEMS AND PRAIRIE BATS HABITAT MANAGEMENT

Grazing systems represent one of the tools in the range manager's tool box to influence the timing, intensity, frequency, and distribution of use. Strategies such as salting, water developments, vegetation manipulation (e.g., fire, spraying, mowing), herding, and others are often used in conjunction with grazing systems to improve grazing use and mitigate any potential negative impacts, such as concentrated grazing on highly desirable primary range. Grazing system efficacy often depends on numerous factors, including stocking rate, livestock type, soils, vegetation, climate, and topography. Proper management is vital with any grazing system and the principles of range management are paramount regardless of the grazing system employed.

Regardless of the grazing system and management strategies employed, producers should manage to maintain the principles of range management:

1. **Stocking** – Balance livestock demand with the available forage supply. Ensure there is sufficient carryover to maintain other rangeland values (*e.g.*, watershed protection) by stocking at or below the grazing capacity.
2. **Distribution** – Control livestock distribution and access to minimize selective grazing behaviour and prevent re-grazing of plants. Management tools and strategies like fencing, salt placement, and water development can be used to encourage better grazing distribution.
3. **Season** – Avoiding grazing rangeland during vulnerable periods; early spring grazing can stress range plants when energy reserves are depleted as new growth is initiated
4. **Rest** – Provide effective rest periods following grazing to manage and maintain vegetation.

Grazing that promotes heterogeneous landscapes will benefit a wide range of bats in Alberta. This requires maintaining structurally heterogeneous cover of native vegetation interspersed with trees, shrubs, wetlands, rocks and woody debris. The following grazing systems were evaluated relative to this desired goal.

Grazing System	**Discussion**
Continuous (season-long) Grazing	

Advantages:	In relatively homogenous landscapes that lack sensitive habitats attractive to cattle, season-long grazing with low stocking rates in combination with proper livestock distribution practices (e.g., mineral licks, offsite watering) may be sufficient to maintain healthy structurally heterogeneous landscapes (Fitch and Adams 1998). Season-long grazing may also help bats habituate to cattle and become familiar with predictable food resources; however, there is no evidence to evaluate the importance of this benefit.
Disadvantages:	Season-long grazing is generally a poor choice for managing habitats used by bats, especially complex rangelands incorporating riparian vegetation. This grazing system fails to prevent access to riparian vegetation during sensitive periods and does not allow for a recovery period for riparian vegetation to establish (Fitch and Adams 1998). Grazing is likely to be most concentrated within productive riparian zones where food, shelter, and drinking water are most accessible for livestock, which may result in damage to important roosting and foraging habitats used by bats.
Complementary Grazing	
Advantages:	Complementary grazing may facilitate deferment of grazing in riparian areas during sensitive periods, such as during the spring when wet conditions make erosion and soil compaction more likely. This could result in improved tree establishment and growth of riparian vegetation, which would improve foraging and roosting habitat used by bats. The benefits of improved riparian vegetation could potentially exceed negative effects of more intensive land use in upland habitats, but would depend on the particular circumstances for the area being considered.
Disadvantages:	Homogenous fields of non-native forage are less likely to be used by bats (Lentini *et al.* 2012), and may support less productive and diverse insect communities (Attwood *et al.* 2008, van Klink *et al.* 2015). If complementary grazing results in an increase in the conversion of native rangeland into improved pasture or cultivated fields, then the net effect on bats may be negative.
Rotational Grazing – Rest Rotation and Deferred Rotation	
Advantages:	These rotational grazing systems can help control the timing and distribution of grazing, and allows periodic rest during the growing season. This can ameliorate patterns of recurrent use often associated with season-long continuous grazing. Rest during the growing season can allow tree seed germination and sapling establishment. In addition, rest periods can allow vegetation and associated arthropod communities to recover, resulting in greater insect prey diversity and abundance (van Klink *et al.* 2015). Rotational grazing systems incorporating riparian zones allow grazing to be timed to avoid periods when cattle are likely to cause the greatest damage.

	This includes avoiding grazing during wet periods, when soils are prone to erosion and compaction, as well as avoiding fall grazing when cottonwood saplings are vulnerable to browsing. Rotational grazing with light to moderate stocking rates, combined with appropriate riparian area management, is likely to be the most beneficial grazing system for bats.
Disadvantages:	Rotational grazing systems may still result in intensive grazing of sensitive habitats, such as riparian zones (Fitch and Adams 1998). This could result in the depletion of structural heterogeneity and high loss of tree seedlings. Although rest periods will help establishment of woody plants, one-year rest periods typical of rest-rotation grazing may not be sufficient for trees to grow out of their vulnerable seeding stage, and prolonged rest periods may be needed (Samuelson and Rood 2004).
Rotational Grazing – High Intensity Grazing	
Advantages:	A greater number of livestock may increase insects attracted to livestock or livestock dung, which are often preyed upon by bats (Downs and Sanderson 2010). Since most bats do not forage in the open prairie, this would only be an advantage if intensive grazing occurs near patches of trees. However, these advantages are unlikely to compensate for the much more substantial disadvantages of intensive grazing systems.
Disadvantages:	Grazing with higher stocking rates can result in the loss of tree regeneration, and reduces vegetation biomass, diversity and structural complexity (Samuelson and Rood 2004, van Klink *et al.* 2015). The likely outcome is a substantial reduction in habitat needed to support insects, leading to an overall reduction in the number and diversity of insect prey (van Klink *et al.* 2015). This loss of tree cover from intensive grazing will deplete or degrade important foraging and roosting habitat used by bats. Additional loss of bat habitat may result if intensive grazing is combined with land improvement practices, such as irrigation, surface leveling, conversion to tame pasture, or the removal of trees, woody debris, or rock piles (Lentini *et al.* 2012). Intensive grazing may also increase the chances of cattle moving into sensitive habitats normally avoided at lower grazing intensities, such as along mudstone slopes.
Riparian Area Grazing	
Advantages:	Properly designed riparian area grazing systems may help maintain critical riparian habitat used for roosting, foraging, hibernation, and as a source of drinking water. Separate fencing of riparian zones allows greater control of the timing and intensity of grazing in riparian areas. More conservative vegetation utilizations rates (i.e., < 65%) can be used in riparian areas to help ensure vigorous growth of riparian vegetation (Fitch and Adams 1998). Use of rotational grazing systems can be used to delay grazing during

	sensitive periods, such as following spring thaw when the soil is wet, or during the late summer and fall when tree seedlings are most vulnerable to browsing (Fitch and Adams 1998). Longer rest periods of a year or more (i.e., under rest-rotation) can be used to allow cottonwood seedlings to establish and grow beyond the stage when they are most vulnerable to grazing (Samuelson and Rood 2004). Managing access to prevent movement through wet areas (e.g., springs), rock fields, mudstone/sandstone slopes, and cottonwood stands will further help prevent damage to important bat habitat features. Corridor / stream bank fencing may be used to prevent access or discourage movement through sensitive areas. Properly managed cattle grazing near riparian areas may benefit bats by creating new foraging opportunities, especially for those bats foraging on insects attracted to dung or livestock (Downs and Sanderson 2010).
Disadvantages:	Riparian areas are the primary habitat for bats in the otherwise open prairies, and provides critical habitat used for roosting, foraging and hibernation by various bat species (Holloway and Barclay 2000, Lausen and Barclay 2006*b*). Although bats may forage around cattle, there is little evidence that any amount of grazing in riparian areas will provide a net benefit to bats. However, poorly managed riparian grazing may greatly reduce cottonwood recruitment, deplete vegetation biomass needed to support insect prey, degrade water quality, and potentially damage roosting structures. Trees used by cavity-roosting bats often have some level of decay, and are therefore more susceptible to damage. Frequent or intensive use of trees for rubbing or loafing by cattle may increase the likelihood of roost trees falling or becoming unsuitable for roosting. Cottonwood habitat is especially important for prairie bats, and is essential for the conservation and management of Western Small-footed Myotis in Alberta (Wilkinson 2012). Because trees are only suitable for tree-roosting bats during the late stages of their life, it will be necessary to incorporate regular prolonged rest periods into rotational grazing systems to ensure a heterogeneous age structure and regular recruitment of new roost trees. Careful, adaptive management of grazing in riparian areas is required to ensure disturbance or degradation of treed areas, roosting sites, and aquatic habitats does not occur.

13 BENEFICIAL MANAGEMENT PRACTICE RECOMMENDATIONS

The following beneficial management practices are expected to provide positive benefits for the conservation of prairie bats. Many of the recommendations focus on two habitats used extensively by bats in prairie landscapes: riparian zones and human buildings. However, much is unknown regarding the biology of prairie bats, and new recommendations will need to be developed as information becomes available.

13.1.1 General Recommendations

Bats in Buildings

Buildings appear to be the most common sites for maternity roosts for at least two of the most abundant prairie bat species – the Little Brown Myotis and Big Brown Bat (Schowalter and Gunson 1979, Schowalter *et al.* 1979, Pybus 1994). This behaviour makes them especially sensitive to disturbance and mortality associated with human activities. Extermination, or the accidental or deliberate entrapment of bats inside a building roost, may result in the mortality of hundreds or, possibly, thousands of individuals. Even if no direct mortality occurs, evictions are associated with much lower reproductive output, and potential loss of a colony from an area (Brigham and Fenton 1986, Neilson and Fenton 1994). Therefore, the management of bats in buildings can have important implications for bat conservation and stewardship.

Bats are an important predator of nocturnal insects, and colonies living in buildings may forage up to several kilometers from their roost (Wilkinson and Barclay 1997). As a result, the loss of a maternity roost could cause substantial increases in insect pest communities over a large area. However, in many cases, humans and bats can coexist without the need for eviction. Preventing entry by bats into human living spaces, and avoiding handling bats, can alleviate many concerns associated with bats in buildings.

The following are some recommendations for managing bats in buildings. Additional resources, including recommendations for the design and installation of bat houses, as well as recommendations for managing bats in buildings, are available from the Alberta Community Bat Program (www.albertabats.ca).

- Identify locations in buildings where bats are roosting and, if possible, take precautionary actions to avoid accidental disturbance, entrapment, or habitat alternations. Use of a building by bats can often be determined by the presence of audible squeaks, as well as the accumulation of bat guano (Figure 4). Common sources of disturbance may include human traffic, animals such as domestic cats, noise, artificial lighting, and smoke (e.g., from barbeques or vehicle exhaust). Adverse habitat alternations include poorly timed structural repairs or renovations, opening or closing doors/windows that are normally not used, and sudden changes to the level of artificial heating.
- Install artificial bat roosts (i.e., bat houses) in areas where naturally occurring roosts have already been degraded (e.g., around residential developments or agricultural lands). Large, multi-chambered bat houses (e.g., Bat Conservation International’s four-chambered bat house, or multi-chambered rocket box) are most likely to provide suitable conditions for maternity colonies. Use of bat houses could be combined with the restoration of natural roosting habitat (e.g., forest restoration) to help bridge the gap until roost trees become usable by bats.

- If eviction of bats from buildings is required, consider installing one or more large multi-chambered bat house to provide alternative accommodation. Ideally, these should be installed well in advance of when eviction is planned so that bats can become familiar with their location.
- Do not evict bats from buildings while they are caring for young, which typically occurs from when they arrive in the spring (around April) to the end of August. Eviction of pregnant bats may lead to the loss of their pup(s), and a substantial reduction in the reproductive output for the colony (Brigham and Fenton 1986). Once pups are born, they are typically left behind in the roost while their mothers go to forage, and they are incapable of leaving the roost on their own.
- Do not trap bats inside of a roost structure. If eviction is necessary, one-way exit devices (e.g., screen flaps) can be used to allow bats to exit but not re-enter, but should not be used until pups have left the roost. In most cases, waiting until bats disperse from building colonies on their own before making structural repairs can alleviate the risk of entrapment. November to February is the ideal time to complete structural repairs, because few bats occupy buildings during this time. However, some Big Brown Bats hibernate in buildings, so incorporating exit options may still be required during the winter months, especially for heated buildings.
- Consider reporting your roost observations. Many basic aspects of bat biology remain poorly understood, including their distribution, habitat use, and long-term population trends. Reporting of roost observations can provide valuable data needed address these knowledge gaps. Voluntary reports of roosting observations can be made to the Alberta Community Bat Program (www.albertabats.ca).
- Help promote public awareness of the benefits of bats and the importance of habitat stewardship. Presentations, field trips, and bat house building workshops have often been successful in building public support for bat conservation. Additional resources are available from the Alberta Community Bat Program.

Other Beneficial Practices

- Design bat-friendly water sources. Comprehensive recommendations for the design of bat-friendly artificial water systems are available from Bat Conservation International (Taylor and Tuttle 2007). Key points include:
    - Use larger troughs or natural structures (e.g., dugouts) for water sources.
    - Avoid obstructions on or above the water surface (e.g, fences, bracing).
    - For automatic troughs with float valves, set the water level to minimize the distance between the surface of the water and the lip of the vessel.
    - Provide a constant, predictable water supply throughout the breeding season (e.g., April to August).
    - Ensure appropriate escape options are available (see below).

- Ensure water troughs, tanks, rain barrels, and other sources of open water are covered or have escape options suitable for bats (Taylor and Tuttle 2007). Key features of escape structures include:
    - Use a rough textured ramp (e.g., wood or mesh) that does not exceed a 45º angle.
    - Ensure the ramp intersects the sides of the vessel, since bats will be trying to climb the sides and may never swim to the middle of the vessel.
    - Ensure the ramp extends all the way to the bottom of the vessel to accommodate drops in the water level.
    - Allow a > 1 m drop into unobstructed flight space at the top of the ramp so that bats can become airborne.
    - Ensure the escape structure is cattle resistant and does not interfere with cattle use.
- Retain existing tree cover whenever possible and create conditions that allow regeneration of naturally treed habitats (e.g., riparian zones). Planting of wildlife friendly trees in already disturbed habitat (e.g., along shelterbelts in cultivated fields or around farmyards) will benefit bats, which in turn, may help control insect pests affecting livestock and crops (Heim *et al.* 2015). Large deciduous species (e.g., *Populus* spp.) will likely provide the greatest benefits to bats (Holloway and Barclay 2000, Olson and Barclay 2013), but other woody species may still create suitable foraging habitat and shelter from the wind. Care should be taken to ensure the planting of trees is compatible with other conservation objectives – for example, do not plant trees in habitat used by Burrowing Owls (*Athene cunicularia*).
- If safety permits, leave large-diameter snags and decaying trees in place, or reduce to a height that still leaves much of the lower trunk intact (ideally to a height > 2 m). If removal of decaying trees and snags is necessary, try to complete work during the winter months (i.e., November to February) when bats are unlikely to be occupying tree cavities.
- Avoid disturbance or destruction of patches of rock, boulders, rugged mudstone/sedimentary terrain, or steep slopes/cliffs – especially in riparian zones. Some bat species, such as the Western Small-footed Myotis and Long-eared Myotis, often roost close to the ground in erosion cavities or under rock piles, and may be sensitive to disturbance. In such areas, the use of off road vehicles (e.g., ATVs), or the clearing of land, may be particularly harmful.
- Bats are particularly sensitive to disturbance during the hibernation period, which may occur between September 1 to April 30. Unauthorized disturbance to known or suspected hibernacula should not occur during this period. However, with the exception of buildings, the only known bat hibernacula on the Alberta prairies occur in rock crevices and erosion holes in riparian habitats, which may be highly cryptic. In addition, these locations may be in close proximity to breeding habitat used during the warmer months (Lausen and Barclay 2006*b*). Therefore, resident bats may benefit from year-round restrictions on disturbances within riparian zones, especially in areas where roosts/hibernacula are likely to occur. Such locations include steep valley slopes and areas of rugged topography.

- Help increase our understanding of bat habitat use by reporting observations of caves, mines or other structures that may support roosting or hibernating bats. Voluntary reports may be made to the Alberta Community Bat Program (www.albertabats.ca). To reduce the risk of disturbance, avoid entering mines or caves if bats are present.
- Equipment coming into contact with bats, roosts, or hibernacula should be cleaned or decontaminated following accepted protocols for preventing the spread of white-nose syndrome (Government of Alberta 2009, Canadian Wildlife Health Cooperative 2015). Decontamination is especially important if equipment will move between bat habitats, such as may occur by recreational cavers, researchers, and pest control professionals. Equipment used in locations known or suspected to have white-nose syndrome should not be used in Alberta, even if decontaminated.
- Report observations of mass bat mortality, or any observation of bats with powdery fungus on their skin, to any Fish and Wildlife office. If possible, take pictures of the affected bats, and record time, place and other pertinent details. Unusual sources of mortality (e.g., drownings) can also be reported to the Alberta Community Bat Program.
- Avoid artificial lighting or select lights with reduced intensity. Although some species forage on insects attracted to street or yard lights, intensive or widespread lighting is likely to have negative consequences for bats (Stone *et al.* 2015). Some bats appear to avoid illuminated areas while foraging or roosting, possibly because of increased predation risk. Persistent illumination of a roost, or roost exit, may lead to abandonment or reduced juvenile growth rates.
- Avoid or minimize the use of pesticides, especially near drainages and wetlands in proximity to riparian zones. Agricultural lands exposed to heavy pesticide use has been associated with significantly lower bat activity, as well as insect abundance and diversity, than agricultural lands where pesticide use was avoided (Wickramasinghe *et al.* 2004). Avoidance of anthelminthic drugs (used to reduce cattle parasites), or selecting varieties with low residual activity in the environment, may also benefit bats that forage on insects found in dung (Downs and Sanderson 2010).
- Avoid water diversion projects or the creation of dams along prairie rivers. These activities result in the dampening of flood cycles, reduce stream flow, and lower the water table, thereby reducing the ability of cottonwood to establish (Rood and Mahoney 1990). Flood events are particularly important for creating conditions suitable for cottonwood seedling establishment. The loss of cottonwood forests, in part because of the reduction of natural flood events, is an important concern for the conservation of prairie bats (Holloway and Barclay 2000, Lausen and Schowalter 2008). Damming of rivers may also result in the direct destruction of bat habitat due to flooding of regions upstream of the dam (Lausen and Schowalter 2008). Furthermore, flooding may disrupt movement corridors along, or between

rivers, which could increase genetic isolation among different subpopulations in the province.

- If a wind energy project is being considered, review applicable regulations, siting recommendations, mitigation measures and other best practices and guidelines related to bats and wind energy. The Government of Alberta has prepared multiple Wildlife Land Use Guidelines applicable to wind energy projects in Alberta that are available on their website. Some of these include the Wildlife Guidelines for Alberta Wind Energy Projects (Government of Alberta 2011) and the Bat Mitigation Framework for Wind Power Development (Government of Alberta 2013). These documents should be reviewed early, because issues with bats and other wildlife may have important implications for the siting, design, regulatory requirements, and budgeting for wind energy projects.
- A full discussion of recommendations for wind energy projects are beyond the scope of this document. However, many bat fatalities can be prevented by avoiding the installation of turbines near high quality bat habitat, or along important movement corridors for bats (e.g., riparian zones; along the foothills) (Government of Alberta 2013). Whenever possible, habitat features attractive to bats (e.g., water troughs, dugouts) should be situated in locations that avoid drawing bats towards, or past, wind turbines.

13.1.2 Grazing Recommendations

Many of the following grazing recommendations involve avoiding degradation of roosting and foraging habitat within riparian areas and other sites where trees and aquatic habitats are present. Off-site watering systems and salt placement are particularly effective tools in relatively homogenous prairie. However, in variable terrain, or in areas with sensitive riparian habitats, additional management actions – such as access restrictions – may be needed to improve cattle distribution and minimize impact to riparian habitats.

- Set conservative utilization rates (e.g., 25% to 65%) in riparian areas to promote tree establishment and vigorous plant growth (Fitch and Adams 1998).
- Place salt or mineral sources at least 1 km from natural water bodies, where possible (Adams *et al.* 1986). Placing salt away from water forces cattle to utilize more of the available range, and reduces the amount of time cattle spend at water sources.
- Provide alternate watering sites (e.g., bat-friendly troughs or dugouts) to reduce the impact of cattle on natural riparian and wetland habitats, and improve distribution. Cattle have been shown to prefer drinking water from a trough, and will often travel farther to reach a trough rather than drinking directly from a stream (Veira 2007). Off-site watering may provide a more reliable and cleaner water source for cattle, and improved water quality can improve livestock health and weight gain. Large pastures may require several strategically placed off-stream water sources to prevent use of streams, unless combined with access restrictions (Veira 2007).

- Discourage movement of cattle through wetlands, treed habitat, steep or erosion prone topography, and rocky terrain. Access restrictions, or use of mineral and water draws, may help manage livestock movement.
- Restrict access to wetlands, water bodies, and watercourses to prevent deterioration of water quality and loss of emergent vegetation needed to support insect prey. Stream bank fencing, may help tree and shrub establishment and regeneration (Miller *et al.* 2010).
- Provide graveled or hardened access points for livestock at select points along a stream or river, ideally in locations that draw cattle away from forested habitat.
- Use rest or deferred rotation grazing systems to ensure sufficient periods of rest and recovery in riparian areas (Fitch and Adams 1998). Several years of rest may be required where the goal is to regenerate new trees like cottonwoods (Fitch and Adams 1998)
- Avoid grazing slopes and riparian areas during the spring, when the soil and stream banks are saturated and more susceptible to erosion, slumping, and other soil damage. Also, avoid heavy use of riparian areas during the fall when woody vegetation is most vulnerable to browsing (Fitch and Adams 1998). The use of riparian pastures – created by fencing upland terrain and riparian landscape units separately – can be used to restrict access to riparian areas during vulnerable periods (Fitch and Adams 1998).
- Where necessary, fence out select riparian areas to restore water quality or vegetation cover, or to prevent damage at key times of the year (i.e., during spring and fall).
- Avoid use of barbed wire for fences installed near aquatic habitats, especially on the top strand. If possible, install fences well away (e.g., > 10 m) from open water, outside of the flight path of visiting bats. Avoid installing fences that bisect water troughs or other sources of open water. If such fences are required, use wooden fences that are easily detectable by bats, and place it well above the height of the water. Also ensure troughs include suitable escape options (see above recommendations for the design of escape options).

14 RESEARCH RECOMMENDATIONS

- Very little is known regarding the winter ecology of bats in Alberta. Although a few cave hibernacula have been located, combined these account for a negligible proportion of the overall bat population. This suggests that most cave hibernacula have not been discovered, or that many bats in Alberta do not hibernate in caves. Observations of hibernacula in the Red Deer River valley indicate that deep-rock crevices or erosion holes that descend below the frost line may be used instead of caves. However, much more research is needed to examine the full range of structures used and their relative importance for bat hibernation.
- Buildings provide roosting habitat for several prairies species (Table 1), and for some, buildings may be critical for their persistence within human modified landscapes. The use of

bat houses has potential to augment available building roosts and mitigate the effect of evictions or roost removals. However, more information is needed to evaluate the importance of anthropogenic habitats for bat conservation, as well as the effectiveness and optimal designs of bat houses (Environment Canada 2015). Information on the location and properties of structures used by bats, effectiveness of different bat house designs, which species are using buildings and bat houses, and microclimates selected by bats using artificial structures would help guide future management recommendations.

- Most studies on the prairies are concentrated in the riparian zones of major rivers or creeks. Although these habitats are undoubtedly important for bats, more research is needed to evaluate the importance of non-riparian prairie habitats that may be attractive to bats, such as cliffs/ridges, treed upland habitats (e.g., shelter belts), farmyards, wetlands (e.g., prairie potholes), and small drainages.
- Most recommendations related to beneficial management practices for bats are unproven. However, advances in ultrasonic recording technology (e.g., bat detectors) have made it feasible to passively collect bat activity data from multiple locations that can span entire seasons. Information on bat activity before and after the implementation of new management approaches (e.g., different grazing systems or different distribution management approaches), along with appropriate controls, would provide valuable data to help guide land management decisions in agricultural areas.
- Basic information on habitat use is still lacking for many prairie bat species, especially for Long-legged Myotis and all three migratory bat species. Information on day roosts used by reproductive females is especially needed.
- Additional information on most aspects of migration is needed. In particular, this includes more complete information on migration corridors used by bats, and their final over-winter destination.
- More research looking into grazing in cottonwood habitats and how this affects tree regeneration.

15 REFERENCES

Personal Communications

Baerwald (Klüg), Brandon. PhD Candidate. University of Regina. Regina, Saskatchewan.

Baerwald, Erin. Post-doctoral Research Fellow. American Wind Wildlife Institute. Regina, Saskatchewan.

Barclay, Robert. Professor and Department Head. Department of Biological Sciences, University of Calgary. Calgary, Alberta.

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Saunders, Matt. Head of Science, Kingston Collegiate and Vocational Institute. Kingston, Ontario.

Schowalter, David (Tim). Retired. Delia, Alberta.

Literature Cited

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

Adams, B.W., W.D. Willms, S. Smoliak, and R.A. Wroe. 1986. Range: Its nature and use. Alberta Forestry, Lands and Wildlife, Public Lands Division, Edmonton, Alberta. 23 pp.

Adams, R.A., and K.M. Thibault. 2006. Temporal resource partitioning by bats at water holes. Journal of Zoology 270(3): 466–472.

Agosta, S.J. 2002. Habitat use, diet and roost selection by the Big Brown Bat (*Eptesicus fuscus*) in North America: a case for conserving an abundant species. Mammal Review 32(3): 179–198.

Alberta Environment and Parks. 2016. Fish and Wildlife Management Information System (FWMIS) database. Database request (completed February 12, 2016).

Aldridge, H.D.J.N., and I.L. Rautenbach. 1987. Morphology, echolocation and resource partitioning in insectivorous bats. Journal of Animal Ecology 56(3): 763–778.

Amelon, S.K., F.R. Thompson, and J.J. Millspaugh. 2014. Resource utilization by foraging eastern red bats (*Lasiurus borealis*) in the Ozark Region of Missouri. Journal of Wildlife Management 78(3): 483–493.

Ancillotto, L., M.T. Serangeli, and D. Russo. 2013. Curiosity killed the bat: domestic cats as bat predators. Mammalian Biology 78(5): 369–373.

Andrusiak, L. 2008. An unusual roosting location of a Hoary Bat (*Lasiurus cinereus*) in British Columbia. Wildlife Afield 5(2): 211–214.

Arbuthnott, D., and R.M. Brigham. 2007. The influence of a local temperature inversion on the foraging behaviour of Big Brown Bats, *Eptesicus fuscus*. Acta Chiropterologica 9(1): 193–201.

Arnett, E.B., and E.F. Baerwald. 2013. Impacts of wind energy development on bats: implications for conservation. Pages 435–456 in R. A. Adams and S. C. Pedersen, editors. Bat Evolution, Ecology, and Conservation. Springer New York.

Arnett, E.B., and J.P. Hayes. 2009. Use of conifer snags as roosts by female bats in western Oregon. Journal of Wildlife Management 73(2): 214–225.

Attwood, S.J., M. Maron, A.P.N. House, and C. Zammit. 2008. Do arthropod assemblages display globally consistent responses to intensified agricultural land use and management? Global Ecology and Biogeography 17(5): 585–599.

Baerwald, E.F., and R.M.R. Barclay. 2009. Geographic variation in activity and fatality of migratory bats at wind energy facilities. Journal of Mammalogy 90(6): 1341–1349.

Baerwald, E.F., and R.M.R. Barclay. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. Journal of Wildlife Management 75(5): 1103–1114.

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(16): R695–R696.

Baerwald, E.F., W.P. Patterson, and R.M.R. Barclay. 2014. Origins and migratory patterns of bats killed by wind turbines in southern Alberta: evidence from stable isotopes. Ecosphere 5(9): 118.

Baker, M.D., and M.J. Lacki. 2006. Day-roosting habitat of female Long-legged Myotis in ponderosa pine forests. Journal of Wildlife Management 70(1): 207–215.

Barclay, R.M.R. 1982. Night roosting behavior of the Little Brown Bat, *Myotis lucifugus*. Journal of Mammalogy 63(3): 464–474.

Barclay, R.M.R. 1984. Observations on the migration, ecology and behavior of bats at Delta-Marsh, Manitoba. Canadian Field-Naturalist 98(3): 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(11): 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 foraging strategies and the consequences for prey selection. Canadian Journal of Zoology 64(12): 2700–2705.

Barclay, R.M.R. 1989. The effect of reproductive condition on the foraging behavior of female Hoary Bats, *Lasiurus cinereus*. Behavioral Ecology and Sociobiology 24(1): 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(1): 165–178.

Barclay, R.M.R. 1993. The biology of prairie bats. Pages 353–357 *in.* Proceedings of the 3rd Prairie Conservation and Endangered Species Workshop. Volume 19.

Barclay, R.M.R. 2012. Variable variation: annual and seasonal changes in offspring sex ratio in a bat. PLoS ONE 7(5): e36344.

Barclay, R.M.R., and L.D. Harder. 2003. Life histories of bats: life in the slow lane. Pages 209–253 in T. H. Kunz and M. B. Fenton, editors. Bat ecology. University of Chicago Press, Chicago, Illinois.

Barclay, R.M.R., and A. Kurta. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. Pages 17–59 in M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in Forests: Conservation and Management. John Hopkins University Press, Baltimore, Maryland.

Belwood, J.J., and M.B. Fenton. 1976. Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 54(10): 1674–1678.

Bergeson, S.M., T.C. Carter, and M.D. Whitby. 2013. Partitioning of foraging resources between sympatric Indiana and Little Brown Bats. Journal of Mammalogy 94(6): 1311–1320.

Bergeson, S.M., T.C. Carter, and M.D. Whitby. 2015. Adaptive roosting gives Little Brown Bats an advantage over endangered Indiana bats. American Midland Naturalist 174(2): 321–330.

Betts, B.J. 1998. Variation in roost fidelity among reproductive female Silver-haired Bats in northeastern Oregon. Northwestern Naturalist 79(2): 59–63.

Black, H.L. 1974. A north temperate bat community: structure and prey populations. Journal of Mammalogy 55(1): 138–157.

Bosakowski, T., and D.G. Smith. 1992. Comparative diets of sympatric nesting raptors in the eastern deciduous forest biome. Canadian Journal of Zoology 70(5): 984–992.

Boughey, K.L., I.R. Lake, K.A. Haysom, and P.M. Dolman. 2011. Improving the biodiversity benefits of hedgerows: How physical characteristics and the proximity of foraging habitat affect the use of linear features by bats. Biological Conservation 144(6): 1790–1798.

Boxall, P.C. 1982. Further observations of predation by Black-billed Magpies on small mammals. Journal of Field Ornithology 53(2): 172–173.

Boyles, J.G., and V. Brack. 2009. Modeling survival rates of hibernating mammals with individual-based models of energy expenditure. Journal of Mammalogy 90(1): 9–16.

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.

Boyles, J.G., and C.K. Willis. 2010. Could localized warm areas inside cold caves reduce mortality of hibernating bats affected by white-nose syndrome? Frontiers in Ecology and the Environment 8(2): 92–98.

Brigham, R.M. 1991. Flexibility in foraging and roosting behaviour by the Big Brown Bat (*Eptesicus fuscus*). Canadian Journal of Zoology 69(1): 117.

Brigham, R.M. 1993. The implications of roost sites for the conservation of bats. Occasional Paper, Provincial Museum of Alberta 361–365.

Brigham, R.M., and M.B. Fenton. 1986. The influence of roost closure on the roosting and foraging behaviour of *Eptesicus fuscus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 64(5): 1128–1133.

Brigham, R.M., and M.B. Saunders. 1990. The diet of Big Brown Bats (*Eptesicus fuscus*) in relation to insect availability in southern Alberta, Canada. Northwest Science 64(1): 7–10.

Broders, H.G., and G.J. Forbes. 2004. Interspecific and intersexual variation in roost-site selection of Northern Long-eared and Little Brown Bats in the greater Fundy National Park Ecosystem. Journal of Wildlife Management 68(3): 602–610.

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.

Brooks, R.T. 2011. Declines in summer bat activity in central New England 4 years following the initial detection of white-nose syndrome. Biodiversity and Conservation 20(11): 2537–2541.

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(4): 976–984.

Canadian Wildlife Health Cooperative. 2015. Canadian national white-nose syndrome decontamination protocol for entering bat hibernacula. Saskatoon, Saskatchewan. 17 pp. <http://www.cwhc-rcsf.ca/docs/WNS_Decontamination_Protocol-Jun2015.pdf>.

Carter, T.C., M.A. Menzel, B.R. Chapman, and K.V. Miller. 2004. Partitioning of food resources by syntopic Eastern Red (*Lasiurus borealis*), Seminole (*L. seminolus*) and Evening (*Nycticeius humeralis*) Bats. American Midland Naturalist 151(1): 186–191.

Carter, T.C., M.A. Menzel, S.F. Owen, J.W. Edwards, J.M. Menzel, and W.M. Ford. 2003. Food habits of seven species of bats in the Allegheny Plateau and Ridge and Valley of West Virginia. Northeastern Naturalist 10(1): 83–88.

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, Alberta.

Chruszcz, B.J., and R.M.R. Barclay. 2002. Thermoregulatory ecology of a solitary bat, *Myotis evotis*, roosting in rock crevices. Functional Ecology 16(1): 18–26.

Chung-MacCoubrey, A.L. 1996. Grassland bats and land management in the Southwest. Pages 54–63 in D. M. Finch, editor. Ecosystem disturbance and wildlife conservation in western grasslands: A symposium proceedings. United States Department of Agriculture, Forest Service, General Technical Report RM-GTR-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(8): 1772–1780.

Clare, E.L., E.E. Fraser, H.E. Braid, M.B. Fenton, and P.D.N. Hebert. 2009. Species on the menu of a generalist predator, the eastern red bat (*Lasiurus borealis*): using a molecular approach to detect arthropod prey. Molecular Ecology 18(11): 2532–2542.

Clare, E.L., W.O.C. Symondson, H. Broders, F. Fabianek, E.E. Fraser, A. MacKenzie, A. Boughen, R. Hamilton, C.K.R. Willis, F. Martinez-Nuñez, A.K. Menzies, K.J.O. Norquay, M. Brigham, J. Poissant, J. Rintoul, R.M.R. Barclay, and J.P. Reimer. 2014a. The diet of *Myotis lucifugus* across Canada: assessing foraging quality and diet variability. Molecular Ecology 23(15): 3618–3632.

Clare, E.L., W.O.C. Symondson, and M.B. Fenton. 2014b. An inordinate fondness for beetles? Variation in seasonal dietary preferences of night-roosting Big Brown Bats (*Eptesicus fuscus*). Molecular Ecology 23(15): 3633–3647.

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.

Coleman, J.L., and R.M.R. Barclay. 2012. Urbanization and the abundance and diversity of Prairie bats. Urban Ecosystems 15(1): 87–102.

Coleman, L.S., W.M. Ford, C.A. Dobony, and E.R. Britzke. 2014. Comparison of radio-telemetric home-range analysis and acoustic detection for Little Brown Bat habitat evaluation. Northeastern Naturalist 21(3): 431–445.

Constantine, D.G. 1966. Ecological observations on lasiurine bats in Iowa. Journal of Mammalogy 47(1): 34–41.

COSEWIC. 2013. COSEWIC assessment and status report on the Little Brown Myotis *Myotis lucifugus* Northern Myotis *Myotis septentrionalis* Tri-colored Bat *Perimyotis subflavus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. xxiv + 93 pp.

Crampton, L.H., and R.M.R. Barclay. 1995. Habitat selection by bats in fragmented and unfragmented aspen mixedwood stands of different ages.

Crampton, L.H., and R.M.R. Barclay. 1998. Selection of roosting and foraging habitat by bats in different-aged aspen mixedwood stands. Conservation Biology 12(6): 1347–1358.

Cryan, P.M. 2003. Seasonal distribution of migratory tree bats (*Lasiurus* and *Lasionycteris*) in North America. Journal of Mammalogy 84(2): 579–593.

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(1): 43–52.

Cryan, P.M., J.W. Jameson, E.F. Baerwald, C.K.R. Willis, R.M.R. Barclay, E.A. Snider, and E.G. Crichton. 2012. Evidence of late-summer mating readiness and early sexual maturation in migratory tree-roosting bats found dead at wind turbines. Plos One 7(10): e47586.

Cryan, P.M., C.A. Stricker, and M.B. Wunder. 2014. Continental-scale, seasonal movements of a heterothermic migratory tree bat. Ecological Applications 24(4): 602–616.

Cryan, P.M., and J.P. Veilleux. 2007. Migration and use of autumn, winter, and spring roosts by tree bats. Pages 153–175 in M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in Forests: Conservation and Management. John Hopkins University Press, Baltimore, Maryland.

Dalquest, W.W., and M.C. Ramage. 1946. Notes on the Long-legged Bat (*Myotis volans*) at Old Fort Tejon and Vicinity, California. Journal of Mammalogy 27(1): 60–63.

Davis, R., and E.L. Cockrum. 1963. Bridges utilized as day-roosts by bats. Journal of Mammalogy 428–430.

Davis, W.H., and R.W. Barbour. 1970. Life history data on some southwestern Myotis. Southwestern Naturalist 15(2): 261–263.

Dennis, P., M.R. Young, and I.J. Gordon. 1998. Distribution and abundance of small insects and arachnids in relation to structural heterogeneity of grazed, indigenous grasslands. Ecological Entomology 23(3): 253–264.

Downs, N.C., and L.J. Sanderson. 2010. Do bats forage over cattle dung or over cattle? Acta Chiropterologica 12(2): 349–358.

Druecker, J.D. 1972. Aspects of reproduction in *Myotis volans*, *Lasionycteris noctivagans*, and *Lasiurus cinereus*. Ph.D., University of New Mexico, New Mexico.

Elmore, L.W., D.A. Miller, and F.J. Vilella. 2004. Selection of diurnal roosts by Red Bats (*Lasiurus borealis*) in an intensively managed pine forest in Mississippi. Forest Ecology and Management 199(1): 11–20.

Elmore, L.W., D.A. Miller, and F.J. Vilella. 2005. Foraging area size and habitat use by Red Bats (*Lasiurus borealis*) in an intensively managed pine landscape in Mississippi. American Midland Naturalist 153(2): 405–417.

Environment Canada. 2015. Recovery Strategy for Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*), and Tri-colored Bat (*Perimyotis subflavus*) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. ix +110 pp.

Everette, A.L., T.J. O'Shea, L.E. Ellison, L.A. Stone, and J.L. McCance. 2001. Bat use of a high-plains urban wildlife refuge. Wildlife Society Bulletin 29(3): 967–973.

Fabianek, F., M.A. Simard, E.B. Racine, and A. Desrochers. 2015. Selection of roosting habitat by male Myotis bats in a boreal forest. Canadian Journal of Zoology 93(7): 539–546.

Faure, P.A., and R.M.R. Barclay. 1994. Substrate-gleaning versus aerial-hawking: plasticity in the foraging and echolocation behaviour of the Long-eared Bat, *Myotis evotis*. Journal of Comparative Physiology A 174(5): 651–660.

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

Findley, J.S., and C. Jones. 1964. Seasonal distribution of the Hoary Bat. Journal of Mammalogy 45(3): 461–470.

Fitch, L., and B.W. Adams. 1998. Can cows and fish co-exist? Canadian Journal of Plant Science 78(2): 191–198.

Foley, J., D. Clifford, K. Castle, P. Cryan, and R.S. Ostfeld. 2011. Investigating and managing the rapid emergence of white-nose syndrome, a novel, fatal, infectious disease of hibernating bats. Conservation Biology 25(2): 223–231.

Ford, W.M., E.R. Britzke, C.A. Dobony, J.L. Rodrigue, and J.B. Johnson. 2011. Patterns of acoustical activity of bats prior to and following white-nose syndrome occurrence. Journal of Fish and Wildlife Management 2(2): 125–134.

Francl, K.E., W.M. Ford, D.W. Sparks, and V. Brack. 2012. Capture and reproductive trends in summer bat communities in West Virginia: assessing the impact of white-nose syndrome. Journal of Fish and Wildlife Management 3(1): 33–42.

Frick, W.F., J.F. Pollock, A.C. Hicks, K.E. Langwig, D.S. Reynolds, G.G. Turner, C.M. Butchkoski, and T.H. Kunz. 2010. An emerging disease causes regional population collapse of a common North American bat species. Science 329(5992): 679–682.

Furlonger, C.L., H.J. Dewar, and M.B. Fenton. 1987. Habitat use by foraging insectivorous bats. Canadian Journal of Zoology 65(2): 284–288.

Geggie, J.F., and M.B. Fenton. 1985. A comparison of foraging by *Eptesicus fuscus* (Chiroptera: Vespertilionidae) in urban and rural environments. Canadian Journal of Zoology 63(2): 263–266.

Government of Alberta. 2009. Addendum to Class Protocol #004: Bat Capture, Handling and Release. Environment and Sustainable Resource Development, Wildlife Management Branch, Edmonton, Alberta. 2 pp.

Government of Alberta. 2011. Wildlife guidelines for Alberta wind energy projects. Fish & Wildlife Division, Sustainable Resource Development, Edmonton, AB. 11 pp.

Government of Alberta. 2012. Alberta wild species general status listing 2010. Revised January 26, 2012. <http://esrd.alberta.ca/fish-wildlife/species-at-risk/albertas-species-at-risk-strategy/general-status-of-alberta-wild-species-2010/documents/SAR-2010WildSpeciesGeneralStatusList-Jan2012.pdf>.

Government of Alberta. 2013. Bat mitigation framework for wind power development. Wildlife land use guidelines. Environment and Sustainable Resource Development, Edmonton, AB. 8 pp.

Government of Alberta. 2014. Species assessed by Alberta's Endangered Species Conservation Committee. Environment and Sustainable Resource Development, Edmonton, Alberta. 2 pp.

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(4): 744–749.

Hamilton, I.M., and R.M.R. Barclay. 1998. Diets of juvenile, yearling, and adult Big Brown Bats (*Eptesicus fuscus*) in southeastern Alberta. Journal of Mammalogy 79(3): 764–771.

Hart, J.A., G.L. Kirkland Jr, and S.C. Grossman. 1993. Relative abundance and habitat use by tree bats, *Lasiurus* spp., in southcentral Pennsylvania. Canadian Field-Naturalist. 107(2): 208–212.

Heim, O., J.T. Treitler, M. Tschapka, M. Knoernschild, and K. Jung. 2015. The importance of landscape elements for bat activity and species richness in agricultural areas. Plos One 10(7): e0134443.

Hendricks, P. 2000. Preliminary Bat Inventory of Caves and Abandoned Mines on BLM Lands, Judith Mountains, Montana. Montana Natural Heritage Program, Helena, MT. 21 pp. <http://mtnhp.org/animal/reports/mammals/BatSurvey_JudithMountains.pdf>. Accessed 6 Feb 2016.

Hendricks, P. 2012. Winter records of bats in Montana. Northwestern Naturalist 93(2): 154–162.

Hendricks, P., J. Johnson, S. Lenard, and C. Currier. 2005. Use of a bridge for day roosting by the Hoary Bat, *Lasiurus cinereus*. Canadian Field-Naturalist 119(1): 132–133.

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(3): 767–774.

Herder, M.J., J.G. Jackson, and B. Cypher. 2000. Roost preferences of Long-legged Myotis in northern Arizona. Transactions of the Western Section of the Wildlife Society 36: 1–7.

Hernández, D.L., J.J. Mell, and M.D. Eaton. 2007. Aerial predation of a bat by an American Crow. Wilson Journal of Ornithology 119(4): 763–764.

Hickey, M.B.C., L. Acharya, and S. Pennington. 1996. Resource partitioning by two species of vespertilionid bats (*Lasiurus cinereus* and *Lasiurus borealis*) feeding around street lights. Journal of Mammalogy 77(2): 325–334.

Hobson, D. 2014. Bat hibernacula monitoring in Alberta for the winter of 2013/4. Western Canada Bat Network Newsletter 24: 3.

Hochachka, W.M., and C.S. Scharf. 1986. Black-billed Magpie, *Pica pica*, predation on bats. Canadian Field-Naturalist. 100(1): 121–122.

Hoffmeister, D.F., and W.L. Downes. 1964. Blue Jays as predators of red bats. Southwestern Naturalist 9(2): 102–102.

Hogberg, L.K., K.J. Patriquin, and R.M.R. Barclay. 2002. Use by bats of patches of residual trees in logged areas of the boreal forest. American Midland Naturalist 148(2): 282–288.

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

Holloway, G.L., and R.M.R. Barclay. 2000. Importance of prairie riparian zones to bats in southeastern Alberta. Ecoscience 7(2): 115–122.

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

Hornung, J.P., and C.L. Rice. 2003. Odonata and wetland quality in southern Alberta, Canada: a preliminary study. Odonatologica 32(2): 119–129.

Hubbs, A.H., and D.T. Schowalter. 2003. Survey of bats in northeastern Alberta. Alberta Sustainable Resource Development, Edmonton, Alberta. 29.

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. Pages 171–177 *in*. J.W. Stringer and D.L. Loftis, eds. Proceedings of the 12th Central Hardwood Forest Conference. General Technical Report SRS-24. USDA Forest Service, Asheville, North Carolina.

Hutchinson, J.T., and M.J. Lacki. 2000. Selection of day roosts by red bats in mixed mesophytic forests. Journal of Wildlife Management 64(1): 87–94.

Hutchinson, J.T., and M.J. Lacki. 2001. Possible microclimate benefits of roost site selection in the red bat, *Lasiurus borealis*, in mixed mesophytic forests of Kentucky. Canadian Field-Naturalist 115(2): 205–209.

Izor, R.J. 1979. Winter range of the Silver-haired Bat. Journal of Mammalogy 60(3): 641–643.

Janos, G.A., and K.V. Root. 2014. Bats do not alter their foraging activity in response to owl calls. American Midland Naturalist 171(2): 375–378.

Jantzen, M.K., and M.B. Fenton. 2013. The depth of edge influence among insectivorous bats at forest–field interfaces. Canadian Journal of Zoology 91(5): 287–292.

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(5): 1261–1270.

Jung, T.S., C.L. Lausen, J.M. Talerico, and B.G. Slough. 2011. Opportunistic predation of a Little Brown Bat (*Myotis lucifugus*) by a Great Horned Owl (*Bubo virginianus*) in southern Yukon. Northwestern Naturalist 92(1): 69–72.

Jung, T.S., and B.G. Slough. 2005. Mortality of Little Brown Bats, *Myotis lucifugus*, in a rodent trap in the boreal forest. Canadian Field-Naturalist 119(4): 589–590.

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(4): 1306–1319.

Kalcounis, M.C., and R.M. Brigham. 1995. Intraspecific variation in wing loading affects habitat use by Little Brown Bats (*Myotis lucifugus*). Canadian Journal of Zoology 73(1): 89–95.

Kalcounis, M.C., and R.M. Brigham. 1998. Secondary use of aspen cavities by tree-roosting Big Brown Bats. Journal of Wildlife Management 62(2): 603–611.

Kalcounis, M.C., and K.R. Hecker. 1996. Intraspecific variation in roost-site selection by Little Brown Bats (*Myotis lucifugus*). Pages 81–90 in R. M. R. Barclay and M. R. Brigham, editors. Bats and Forests Symposium. October 19–21, 1995. Research Branch, Ministry of Forests.

Kalcounis, M.C., K.A. Hobson, R.M. Brigham, and K.R. Hecker. 1999. Bat activity in the boreal forest: Importance of stand type and vertical strata. Journal of Mammalogy 80(2): 673–682.

Kalda, O., R. Kalda, and J. Liira. 2015. Multi-scale ecology of insectivorous bats in agricultural landscapes. Agriculture, Ecosystems & Environment 199: 105–113.

van Klink, R., F. van der Plas, C.G.E. (Toos) van Noordwijk, M.F. WallisDeVries, and H. Olff. 2015. Effects of large herbivores on grassland arthropod diversity. Biological Reviews of the Cambridge Philosophical Society 90(2): 347–366.

Klug, B.J., D.A. Goldsmith, and R.M.R. Barclay. 2012. Roost selection by the solitary, foliage-roosting Hoary Bat (*Lasiurus cinereus*) during lactation. Canadian Journal of Zoology 90(3): 329–336.

Koehler, C.E., and R.M.R. Barclay. 2000. Post-natal growth and breeding biology of the Hoary Bat (*Lasiurus cinereus*). Journal of Mammalogy 81(1): 234–244.

Kunz, T.H. 1971. Reproduction of some Vespertilionid bats in central Iowa. American Midland Naturalist 86(2): 477–486.

Kunz, T.H. 1982a. Roosting ecology of bats. Pages 1–55 in T. H. Kunz, editor. Ecology of Bats. Plenum Press, New York, New York.

Kunz, T.H. 1982b. *Lasionycteris noctivagans*. Mammalian Species 1–5.

Kunz, T.H., J.A. Wrazen, and C.D. Burnett. 1998. Changes in body mass and fat reserves in pre-hibernating Little Brown Bats (*Myotis lucifugus*). Ecoscience 5(1): 8–17.

Kurta, A. 1990. *Eptesicus fuscus*. Mammalian species 356: 1–10.

Kurta, A. 2000. Bats on the surface: the need for shelter, food, and water. Pages 197–204 in K. C. Vories and D. Throgmorton, editors. Proceedings of Bat Conservation and Mining: A Technical Interactive Forum. U.S. Department of Interior, Office of Surface Mining, Alton, Illinois and Coal Research Center, Southern Illinois University, Carbondale, Illinois, Carbondale.

Kurta, A., G.P. Bell, K.A. Nagy, and T.H. Kunz. 1989. Energetics of pregnancy and lactation in freeranging Little Brown Bats (*Myotis lucifugus*). Physiological Zoology 62(3): 804–818.

Lacki, M.J., M.D. Baker, and J.S. Johnson. 2010. Geographic variation in roost-site selection of Long-legged Myotis in the Pacific Northwest. Journal of Wildlife Management 74(6): 1218–1228.

Lacki, M.J., M.D. Baker, and J.S. Johnson. 2012. Temporal dynamics of roost snags of Long-legged Myotis in the Pacific Northwest, USA. Journal of Wildlife Management 76(6): 1310–1316.

Lacki, M.J., J.S. Johnson, and M.D. Baker. 2013. Temperatures beneath bark of dead trees used as roosts by *Myotis volans* in forests of the Pacific Northwest, USA. Acta Chiropterologica 15(1): 143–151.

Lacki, M.J., J.S. Johnson, L.E. Dodd, and M.D. Baker. 2007. Prey consumption of insectivorous bats in coniferous forests of north-central Idaho. Northwest Science 81(3): 199–205.

Langwig, K.E., W.F. Frick, J.T. Bried, A.C. Hicks, T.H. Kunz, and A.M. Kilpatrick. 2012. Sociality, density-dependence and microclimates determine the persistence of populations suffering from a novel fungal disease, white-nose syndrome. Ecology Letters 15(9): 1050–1057.

Lausen, C.L. 2003. Roosting ecology of the Western Small-footed Bat (*Myotis ciliolabrum*) in southeastern Alberta. Research Report for Mountain Equipment Co-op. 20 pp.

Lausen, C.L. 2004. Bat survey of Writing on Stone Provincial Park, a compilation of work since 1985. 29.

Lausen, C.L. 2006. 2005-2006 Bat survey of the middle Red Deer and Battle Rivers. Unpublished report prepared for Alberta Natural Heritage Information Centre, Edmonton, Alberta. 22 pp.

Lausen, C.L. 2007. Roosting ecology and landscape genetics of prairie bats. University of Calgary, Calgary, Alberta.

Lausen, C.L. 2015. Seeking silver in southeast British Columbia mines: hibernation ecology of Silver-haired Bats. Western Canada Bat Network Newsletter (26): 12.

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(6): 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 260(3): 235–244.

Lausen, C.L., and R.M.R. Barclay. 2006a. Benefits of living in a building: Big Brown Bats (*Eptesicus fuscus*) in rocks versus buildings. Journal of Mammalogy 87(2): 362–370.

Lausen, C.L., and R.M.R. Barclay. 2006b. Winter bat activity in the Canadian prairies. Canadian Journal of Zoology 84(8): 1079–1086.

Lausen, C.L., and D. Player. 2014. Eastern red bat (*Lasiurus borealis*) occurrence in northern Alberta. Northwestern Naturalist 95(3): 219–227.

Lausen, C.L., and D. Schowalter. 2008. Status of the Western Small-footed Bat (*Myotis ciliolabrum*) in Alberta. Ann Arbor.

Lausen, C.L., J. Waithaka, and D.P. Tate. 2014. Bats of Nahanni National Park Reserve and surrounding areas, Northwest Territories. Northwestern Naturalist 95(3): 186–196.

Lee Foote, A., and C.L. Rice Hornung. 2005. Odonates as biological indicators of grazing effects on Canadian prairie wetlands. Ecological Entomology 30(3): 273–283.

Lentini, P.E., P. Gibbons, J. Fischer, B. Law, J. Hanspach, and T.G. Martin. 2012. Bats in a farming landscape benefit from linear remnants and unimproved pastures. PLoS ONE 7(11): e48201.

Lewis, S.E. 1995. Roost fidelity of bats: a review. Journal of Mammalogy 76(2): 481–496.

Lima, S.L., and J.M. O'Keefe. 2013. Do predators influence the behaviour of bats? Biological Reviews 88(3): 626–644.

Limpert, D.L., D.L. Birch, M.S. Scott, M. Andre, and E. Gillam. 2007. Tree selection and landscape analysis of eastern red bat day roosts. Journal of Wildlife Management 71(2): 478–486.

Loeb, S.C., and J.M. Keefe. 2006. Habitat use by forest bats in South Carolina in relation to local, stand, and landscape characteristics. Journal of Wildlife Management 70(5): 1210–1218.

Long, C.A. 1964. Red bat impaled on barbed wire. Transactions of the Kansas Academy of Science (1903-) 67(1): 201–201.

Lumsden, L.F., and A.F. Bennett. 2005. Scattered trees in rural landscapes: foraging habitat for insectivorous bats in south-eastern Australia. Biological Conservation 122(2): 205–222.

Mager, K.J., and T.A. Nelson. 2001. Roost-site selection by eastern red bats (*Lasiurus borealis*). American Midland Naturalist 145(1): 120–126.

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

Mattson, T.A., S.W. Buskirk, and N.L. Slanlon. 1996. Roost sites of the Silver-haired Bat (*Lasionycteris noctivagans*) in the Black Hills, South Dakota. Great Basin Naturalist 56(3): 247–253.

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(1): 235–245.

Menzel, M.A., T.C. Carter, L.R. Jablonowski, B.L. Mitchell, J.M. Menzel, and B.R. Chapman. 2001. Home range size and habitat use of Big Brown Bats (*Eptesicus fuscus*) in a maternity colony located on a rural-urban interface in the southeast. Journal of the Elisha Mitchell Scientific Society 117: 36–45.

Menzel, M.A., S.F. Owen, W.M. Ford, J.W. Edwards, P.B. Wood, B.R. Chapman, and K.V. Miller. 2002. Roost tree selection by Northern Long-eared Bat (*Myotis septentrionalis*) maternity colonies in an industrial forest of the central Appalachian mountains. Forest Ecology and Management 155(1-3): 107–114.

Metheny, J.D., M.C. Kalcounis-Rueppell, C.K.R. Willis, K.A. Kolar, and R.M. Brigham. 2008. Genetic relationships between roost-mates in a fission–fusion society of tree-roosting Big Brown Bats (*Eptesicus fuscus*). Behavioral Ecology and Sociobiology 62(7): 1043–1051.

Miller, J., D. Chanasyk, T. Curtis, T. Entz, and W. Willms. 2010. Influence of streambank fencing with a cattle crossing on riparian health and water quality of the Lower Little Bow River in Southern Alberta, Canada. Agricultural Water Management 97(2): 247–258.

Moorman, C.E., K.R. Russell, M.A. Menzel, S.M. Lohr, J.E. Ellenberger, and D.H. Van Lear. 1999. Bats roosting in deciduous leaf litter. Bat Research News 40(3): 74–75.

Mormann, B.M., and L.W. Robbins. 2007. Winter roosting ecology of eastern red bats in southwest Missouri. Journal of Wildlife Management 71(1): 213–217.

Nagorsen, D.W., and R.M. Brigham. 1993. Bats of British Columbia. Volume 1. Mammals of British Columbia, UBC Press, Vancouver, British Columbia.

Natural Regions Committee. 2006. Natural regions and subregions of Alberta. Compiled by DJ Downing and WW Pettapiece. Government of Alberta. vi + 254 pp.

Neilson, A.L., and M.B. Fenton. 1994. Responses of Little Brown Myotis to exclusion and to bat houses. Wildlife Society Bulletin 22(1): 8–14.

Neubaum, D.J., T.J. O'Shea, and K.R. Wilson. 2006. Autumn migration and selection of rock crevices as hibernacula by Big Brown Bats in Colorado. Journal of Mammalogy 87(3): 470–479.

Nixon, A.E., J.C. Gruver, and R.M.R. Barclay. 2009. Spatial and temporal patterns of roost use by Western Long-eared Bats (*Myotis evotis*). American Midland Naturalist 162(1): 139–147.

Norberg, U.M., and J.M.V. Rayner. 1987. Ecological morphology and flight in bats (Mammalia: Chiroptera): Wing adaptations, flight performance, foraging strategy and echolocation. Philosophical Transactions of the Royal Society B: Biological Sciences 316(1179): 335–427.

Ober, H.K., and J.P. Hayes. 2008. Prey selection by bats in forests of western Oregon. Journal of Mammalogy 89(5): 1191–1200.

O'Keefe, J.M., S.C. Loeb, J.D. Lanham, and H.S. Hill Jr. 2009. Macrohabitat factors affect day roost selection by Eastern Red Bats and eastern pipistrelles in the southern Appalachian Mountains, USA. Forest Ecology and Management 257(8): 1757–1763.

Olson, C.R. 2011. The roosting behaviour of Little Brown Bats (*Myotis lucifugus*) and Northern Long-eared Bats (*Myotis septentrionalis*) in the boreal forest of northern Alberta. M.Sc. Thesis, University of Calgary, Calgary, Alberta.

Olson, C.R., and R.M.R. Barclay. 2013. Concurrent changes in group size and roost use by reproductive female Little Brown Bats (*Myotis lucifugus*). Canadian Journal of Zoology 91(3): 149–155.

Olson, C.R., D.P. Hobson, and M.J. Pybus. 2011. Changes in population size of bats at a hibernaculum in Alberta, Canada, in relation to cave disturbance and access restrictions. Northwestern Naturalist 92(3): 224–230.

Ormsbee, P. 1996. Selection of day roosts by female Long-legged Myotis (*Myotis volans*) in forests of the central Oregon Cascades. M.Sc. Thesis, Oregon State University, Corvallis, Oregon.

Ormsbee, P.C., J.D. Kiser, and S.I. Perlmeter. 2007. Importance of night roosts to the ecology of bats. Pages 129–149 in M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in Forests: Conservation and Management. John Hopkins University Press, Baltimore, Maryland.

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(2): 596–603.

Parsons, H.J., D.A. Smith, and R.F. Whittam. 1986. Maternity colonies of Silver-haired Bats, *Lasionycteris noctivagans*, in Ontario and Saskatchewan. Journal of Mammalogy 67(3): 598–600.

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(1-3): 559–570.

Perkins, J.M., J.M. Barss, and J. Peterson. 1990. Winter records of bats in Oregon and Washington. Northwestern Naturalist 71(2): 59–62.

Perlik, M.K., B.R. McMillan, and J.D. Krenz. 2012. Food habits of the Hoary Bat in an agricultural landscape. Minnesota Academy of Science Journal 75: 1–6.

Perlmeter, S.I. 1995. Bats and bridges: A field study of the thermal conditions and social organization of night roosts in the Willamette National forest. M.Sc. Thesis, York University, North York, Ontario.

Perry, R.W., and R.E. Thill. 2007. Roost characteristics of Hoary Bats in Arkansas. American Midland Naturalist 158(1): 132–138.

Perry, R.W., R.E. Thill, and S.A. Carter. 2007. Sex-specific roost selection by adult red bats in a diverse forested landscape. Forest Ecology and Management 253: 48–55.

Psyllakis, J.M., and R.M. Brigham. 2006. Characteristics of diurnal roosts used by female Myotis bats in sub-boreal forests. Forest Ecology and Management 223: 93–102.

Pybus, M. 1994. Bats of Alberta “The Real Story.” Alberta Environmental Protection, Edmonton, Alberta.

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(2): 612–621.

Rancourt, S.J., M.I. Rule, and M.A. O'Connell. 2005. Maternity roost site selection of Long-eared Myotis, *Myotis evotis*. Journal of Mammalogy 86(1): 77–84.

Reimer, J.P., E.F. Baerwald, and R.M.R. Barclay. 2010. Diet of Hoary (*Lasiurus cinereus*) and Silver-haired (*Lasionycteris noctivagans*) Bats while migrating through southwestern Alberta in late summer and autumn. American Midland Naturalist 164(2): 230–237.

Reimer, J.P., C.L. Lausen, R.M. Barclay, S. Irwin, and M.K. Vassal. 2014. Bat activity and use of hibernacula in Wood Buffalo National Park, Alberta. Northwestern Naturalist 95(3): 277–288.

Riskin, D.K., and M.J. Pybus. 1998. The use of exposed diurnal roosts in Alberta by the Little Brown Bat, *Myotis lucifugus*. Canadian Journal of Zoology 76(4): 767–770.

Rodhouse, T.J., and K.J. Hyde. 2014. Roost and forage site fidelity of Western Small-footed Myotis (*Myotis ciliolabrum*) in an Oregon desert canyon. Western North American Naturalist 74(2): 241–248.

Rolseth, S., C. Koehler, and R. Barclay. 1994. Differences in the diets of juvenile and adult Hoary Bats, *Lasiurus cinereus*. Journal of Mammalogy 75(2): 394–398.

Rood, S.B., and J.M. Mahoney. 1990. Collapse of riparian poplar forests downstream from dams in western prairies: Probable causes and prospects for mitigation. Environmental Management 14(4): 451–464.

Saab, V. 1999. Importance of spatial scale to habitat use by breeding birds in riparian forests: a hierarchical analysis. Ecological Applications 9(1): 135–151.

Samuelson, G.M., and S.B. Rood. 2004. Differing influences of natural and artificial disturbances on riparian cottonwoods from prairie to mountain ecoregions in Alberta, Canada. Journal of Biogeography 31(3): 435–450.

Sarkozi, D.L., and D.M. Brooks. 2003. Eastern Red Bat (*Lasiurus borealis*) impaled by a Loggerhead Shrike (*Lanius ludovicianus*). Southwestern Naturalist 48(2): 301–303.

Saunders, M.B. 1989. Physical and thermal characteristics of a natural maternity roost used by Little Brown Bats (*Myotis lucifugus*) and Long-legged Bats (*Myotis volans*). Unpublished manuscript, Calgary, Alberta. 13 pp.

Saunders, M.B., and R.M.R. Barclay. 1992. Ecomorphology of insectivorous bats: a test of predictions using two morphologically similar species. Ecology 73(4): 1335–1345.

Schowalter, D.B. 1978. Some western Canada bat records. Blue Jay 36(1): 49–50.

Schowalter, D.B. 1979. Notes on the distribution of bats in Alberta and Saskatchewan. Blue Jay 37(3): 179–187.

Schowalter, D.B. 1980. Swarming, reproduction, and early hibernation of *Myotis lucifugus* and M. volans in Alberta, Canada. Journal of Mammalogy 61(2): 350–354.

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(1): 48–54.

Schowalter, D.B., J.R. Gunson, and L.D. Harder. 1979. Life-history characteristics of Little Brown Bats (*Myotis lucifugus*) in Alberta. Canadian Field-Naturalist 93(3): 243–251.

Schwab, N.A. 2006. Roost-site selection and potential prey sources after wildland fire for two insectivorous bat species (*Myotis evotis* and *Myotis lucifugus*) in mid-elevation forests of western Montana. M.Sc. Thesis, University of Montana, Missoula, Montana.

Sealy, S. 1999. Saw-whet Owls (*Aegolius acadicus brooksi*) on the Queen Charlotte Islands. Western Birds 30: 200–205.

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

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

Snider, E.A., P.M. Cryan, and K.R. Wilson. 2013. Roost selection by western Long-eared Myotis (*Myotis evotis*) in burned and unburned piñon–juniper woodlands of southwestern Colorado. Journal of Mammalogy 94(3): 640–649.

Solick, D.I., and R.M.R. Barclay. 2006a. Thermoregulation and roosting behaviour of reproductive and nonreproductive female Western Long-eared Bats (*Myotis evotis*) in the Rocky Mountains of Alberta. Canadian Journal of Zoology 84(4): 589–599.

Solick, D.I., and R.M.R. Barclay. 2006b. Morphological differences among western Long-eared Myotis (*Myotis evotis*) populations in different environments. Journal of Mammalogy 87(5): 1020–1026.

Solick, D.I., and R.M.R. Barclay. 2007. Geographic variation in the use of torpor and roosting behaviour of female Western Long-eared Bats. Journal of Zoology 272(4): 358–366.

Soper, J.D. 1964. The mammals of Alberta. Alberta Department of Industry and Development, Edmonton, Alberta.

Stone, E.L., S. Harris, and G. Jones. 2015. Impacts of artificial lighting on bats: a review of challenges and solutions. Mammalian Biology 80(3): 213–219. Special Issue: Bats as Bioindicators.

Swenson, J.E., and G.F. Shanks. 1979. Noteworthy records of bats from northeastern Montana. Journal of Mammalogy 60(3): 650–652.

Swystun, M.B., J.E. Lane, and R.M. Brigham. 2007. Cavity roost site availability and habitat use by bats in different aged riparian cottonwood stands. Acta Chiropterologica 9(1): 183–191.

Taylor, D.A.., and M.D. Tuttle. 2007. Water for Wildlife: A handbook for ranchers and range managers. Bat Conservation International. 18 pp. <http://www.batcon.org/pdfs/water/bciwaterforwildlife.pdf>.

Thomas, H.H., P.R. Moosman, J.P. Veilleux, and J. Holt. 2012. Foods of bats (family Vespertilionidae) at five locations in New Hampshire and Massachusetts. Canadian Field-Naturalist 126(2): 117–124.

Tuttle, M.D., and J. Kennedy. 2011. Thermal requirements during hibernation. Pages 73–82 *in*. Bat Conservation and Management Workshop – Arizona, Course Booklet. Bat Conservation International, Austin, Texas.

Valdez, E.W., and P.M. Cryan. 2009. Food habits of the Hoary Bat (*Lasiurus cinereus*) during spring migration through New Mexico. The Southwestern Naturalist 54(2): 195–200.

Valdez, E.W., and P.M. Cryan. 2013. Insect prey eaten by Hoary Bats (*Lasiurus cinereus*) prior to fatal collisions with wind turbines. Western North American Naturalist 73(4): 516–524.

Valdez, E.W., and T.J. O’Shea. 2014. Seasonal shifts in the diet of the Big Brown Bat (*Eptesicus fuscus*), Fort Collins, Colorado. Southwestern Naturalist 59(4): 509–514.

Veira, D.M. 2007. Meeting water requirements of cattle on the Canadian prairies. The Rangeland Journal 29(1): 79–86.

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(2): 117–125.

Vonhof, M.J., and R.M. Barclay. 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology 74(10): 1797–1805.

Vonhof, M.J., and R.M.R. Barclay. 1997. Use of tree stumps as roosts by the Western Long-eared Bat. Journal of Wildlife Management 61(3): 674–684.

Vonhof, M.J., and J.C. Gwilliam. 2007. Intra- and interspecific patterns of day roost selection by three species of forest-dwelling bats in Southern British Columbia. Forest Ecology and Management 252(1-3): 165–175.

Vonhof, M.J., and D. Hobson. 2000. Survey of bats of central and northwestern Alberta. Alberta Species at Risk Report No. 4. Alberta Sustainable Resource Development, Edmonton, Alberta. 33 pp.

Vonhof, M.J., and A.L. Russell. 2015. Genetic approaches to the conservation of migratory bats: a study of the Eastern Red Bat (*Lasiurus borealis*). Peerj 3: e983.

Waldien, D.L., and J.P. Hayes. 2001. Activity areas of female Long-eared Myotis in coniferous forests in western Oregon. Northwest Science 75(3): 307–314.

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(3): 785–796.

Walters, B.L., C.M. Ritzi, D.W. Sparks, and J.O. Whitaker. 2007. Foraging behavior of Eastern Red Bats (*Lasiurus borealis*) at an urban-rural interface. American Midland Naturalist 157(2): 365–373.

Warner, R.M. 1985. Interspecific and temporal dietary variation in an Arizona bat community. Journal of Mammalogy 66(1): 45–51.

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

Whitaker, J.O. 1972. Food habits of bats from Indiana. Canadian Journal of Zoology 50(6): 877–883.

Whitaker, J.O. 1995. Food of the Big Brown Bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. The American Midland Naturalist 134(2): 346–360.

Whitaker, J.O. 2004. Prey selection in a temperate zone insectivorous bat community. Journal of Mammalogy 85(3): 460–469.

Whitaker, J.O., and S.L. Gummer. 1992. Hibernation of the Big Brown Bat, *Eptesicus fuscus*, in buildings. Journal of Mammalogy 73(2): 312–316.

Whitaker, J.O., R.K. Rose, and T.M. Padgett. 1997. Food of the red bat *Lasiurus borealis* in winter in the great dismal swamp, North Carolina and Virginia. American Midland Naturalist 137(2): 408–411.

Whitaker Jr, J.O., C. Maser, and S.P. Cross. 1981. Food habits of eastern Oregon bats, based on stomach and scat analyses. Northwest Science 55(4): 281–292.

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

Wickramasinghe, L.P., S. Harris, G. Jones, and N. Vaughan Jennings. 2004. Abundance and species richness of nocturnal insects on organic and conventional farms: effects of agricultural intensification on bat foraging. Conservation Biology 18(5): 1283–1292.

Wilkinson, L.C. 2012. Western Small-footed Bat conservation management plan. Alberta Environment and Sustainable Resource Development, Edmonton, AB.

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(3): 279–285.

Willis, C.K.R., and R.M. Brigham. 2003. New records of the Eastern Red Bat, *Lasiurus borealis*, from Cypress Hills Provincial Park, Saskatchewan: A response to climate change? Canadian Field-Naturalist 117(4): 651–654.

Willis, C.K.R., and R.M. Brigham. 2004. Roost switching, roost sharing and social cohesion: forest-dwelling Big Brown Bats, *Eptesicus fuscus*, conform to the fission-fusion model. Animal Behaviour 68(3): 495–505.

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(1): 85–94.

Willis, C.K.R., and R.M. Brigham. 2007. Social thermoregulation exerts more influence than microclimate on forest roost preferences by a cavity-dwelling bat. Behavioral Ecology and Sociobiology 62(1): 97–108.

Willis, C.K.R., C.M. Voss, and R.M. Brigham. 2006. Roost selection by forest-living female Big Brown Bats (*Eptesicus fuscus*). Journal of Mammalogy 87(2): 345–350.

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.M., J.P. Reimer, D. Allaire, and C.L. Lausen. 2014. Diversity and distribution of bats in the Northwest Territories. Northwestern Naturalist 95(3): 197–218.

Wisely, A.N. 1978. Bat dies on barbed wire fence. Blue Jay 36: 53.