Saskatchewan
Prairie Conservation
Action Plan

Guide to Managing for Optimal Habitat Attributes:

Little Brown Bat *(Myotis lucifugus)*

May, 2020

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ABOUT THIS GUIDE

A NEW APPROACH TO MANAGING FOR SPECIES AT RISK

The intent of this guide is to determine site and landscape-scale habitat features that are optimal for species at risk at different life stages, as well as important non-habitat related beneficial management practices. As habitat for species at risk declines and threats to populations increase in jurisdictions outside Canada, it becomes critical to provide optimal conditions on what remains in Canada if we are to conserve or recover a species.

This First Approximation of the guide for the Little Brown Bat should be considered a living or dynamic document that will continually evolve. As our knowledge of prairie species at risk improves with research and monitoring, this guide will need to be periodically revisited and updated.

WHO SHOULD USE THIS GUIDE?

Most species at risk in Saskatchewan exist on working agricultural lands that often support grazing livestock and sometimes support annual or perennial crops. Some occur in forested areas that are managed for industrial forest products or local use of poles, posts or firewood. This guide provides habitat targets and non-habitat related beneficial management practices (BMPs) for land managers who may have the opportunity to aid in the conservation of species at risk on the land under their control. Additionally, the habitat targets and BMPs may be used by conservation organizations in designing results-based agreements with land managers.

The Environmental Benefit Index is designed to be used by any stakeholder to prioritize sites and/or projects for conservation and recovery programs, or by land managers to evaluate the value of their property for a particular species.

HOW TO USE THIS GUIDE

This guide is presented in two parts. The first part summarizes the important spatial and temporal needs of the species and presents habitat targets and non-habitat related BMPs. Habitat targets are presented at the site scale and categorized by the type of habitat required at different life stages. Site scale targets are those attributes that the individual prefers at a certain time (e.g., roosting, foraging, staging or migrating) or in a certain portion of their home range. Site habitat targets are most commonly physical vegetation, water, soil and/or topography parameters, but may also include such attributes as configuration of land cover or habitats, and presence/absence of human infrastructure. The rationale for each target or BMP is also provided so land managers can readily understand the relationship between the target and use of habitat by the species.

Guides have been prepared for individual species. Habitat targets for individual species give the land manager the choice of species they wish to benefit. Managing for a single species may result in habitat that is undesirable for another species. Conflicts between species are addressed in the Environmental Benefit Index.

The second part of the guide presents an index (Environmental Benefit Index) that places values on the habitat targets and BMPs in combination with other considerations. An Environmental Benefit Index (EBI) is a compound index that considers multiple environmental factors when determining an ecological outcome. EBIs can be used to evaluate and prioritize opportunities for conservation programs. An EBI is of considerable importance in determining priority sites to invest in, particularly when funds are limited.

The overall goal of the EBIs for species at risk habitat is to ensure maximum environmental value for an investment in results-based conservation programming. The EBI has several potential uses including:

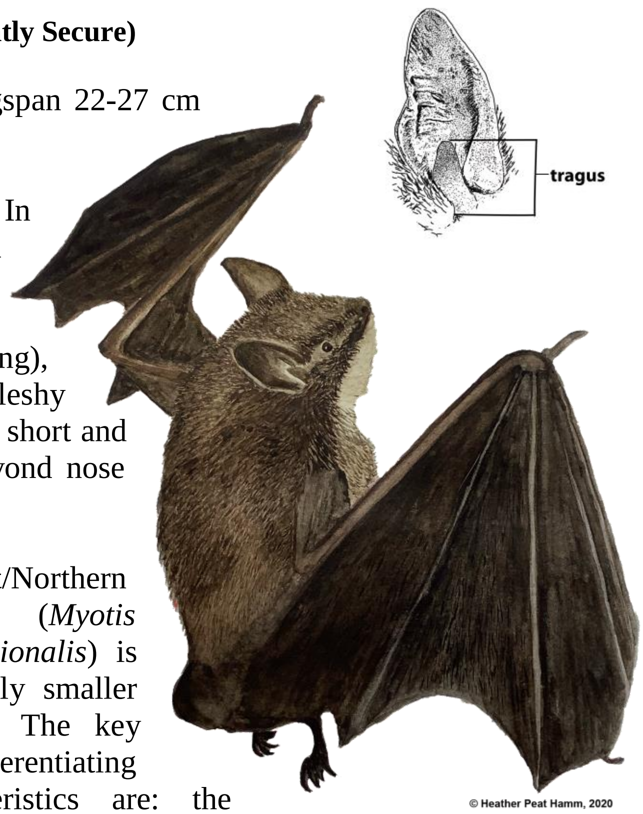
- To geographically target the most important locations,
- To evaluate and rank candidate properties or projects for their environmental benefit,
- To rank the environmental benefit of candidate properties or projects by cost (or bid), and
- To evaluate projects over time to determine if environmental values are being improved or maintained, or to evaluate the efficiency of the investment over time.

EBIs were identified as a method to target programming and prioritize participation in the design of the Prairie Beef & Biodiversity program (Commission for Environmental Cooperation, 2013). EBIs were subsequently developed for the Greater Sage-Grouse (Ranchers Stewardship Alliance Inc., 2014), Piping Plover (PCAP SK, 2017), Burrowing Owl (PCAP SK, unpublished), Northern Leopard Frog (PCAP SK, 2018a), Loggerhead Shrike (PCAP SK, 2018b), Baird's Sparrow (PCAP SK, 2019a) and Chestnut-collared Longspur (PCAP SK, 2019b).

LITTLE BROWN BAT MODULE

LITTLE BROWN BAT IDENTIFICATION

COSEWIC status: Endangered
S-Rank for Saskatchewan: S4B, S4N (Apparently Secure)



Size - 5.5 - 11.0 g (0.2 - 0.4 ounces); wingspan 22-27 cm (8.8-10.8")

Longevity - Bats are long lived mammals. In Alberta, a recaptured banded Little Brown Bat was known to be at least 39 years old.

Features – small size (6 – 10 cm (2.5-4") long), brown fur, dark brown wings, tragus (the fleshy base at the front of the opening of the ear) is short and blunt (see diagram); ears do not extend beyond nose when pressed forward.

Similar species – Northern Long-eared Bat/Northern Myotis (*Myotis septentrionalis*) is a slightly smaller species. The key differentiating characteristics are: the tragus of Northern Myotis is long, slender and pointed; their ears extend beyond their noses when pressed forward. The Big Brown Bat (*Eptesicus fuscus*) is a species that commonly roosts in buildings and is likely to be observed by people. Big Brown Bats look very similar to Little Brown Bats, but are typically more than twice as big. The sides of a Big Brown Bat's nose have a puffy or swollen appearance whereas Little Brown Bats typically have slender noses.

Little Brown Bat (*Myotis lucifugus*), also known as Little Brown Myotis, ranges widely across Canada, from Newfoundland to British Columbia, northward to the treeline, potentially inhabiting all areas of Saskatchewan. Figure 1 shows known and potential occurrences of Little Brown Bat/Myotis in Saskatchewan.

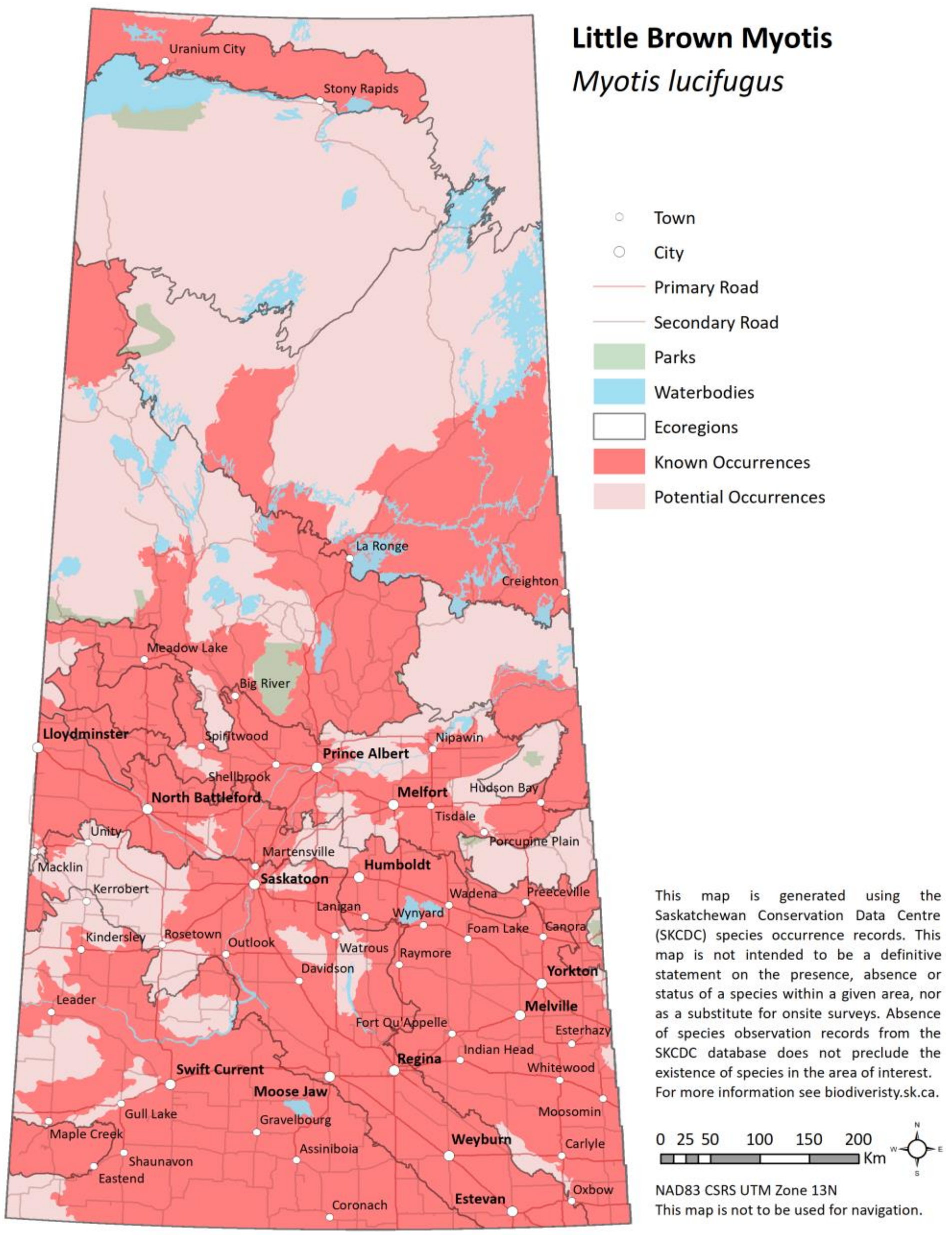


Figure 1. Range map of known and potential occurrences for Little Brown Bat/Myotis (Saskatchewan Conservation Data Centre, 2019). This map is not intended to be a definitive statement on the presence, absence or status of a species within a given area, nor as a substitute for onsite surveys.

The annual breeding cycle of the Little Brown Bat begins with the swarming in the late summer when mating takes place in a promiscuous and indiscriminate system in the vicinity of hibernacula. The bats then settle into hibernation within the hibernacula, although not always at the same site at which they mated. Females store sperm over winter until they ovulate and become pregnant after emergence from the hibernacula in the spring.

REPRODUCTION

In spring, females form maternity colonies, separate from the males and non-reproducing females, where they give birth to and raise pups. Little Brown Bat females produce one pup each year and do not typically reproduce until their second or third year. Maternity colonies are located in warm sites such as cavities in trees, rock crevices, under bridges, bat houses and in attics of buildings. Females typically return to reproduce in the maternity colonies in which they were born. Gestation is 50-60 days and females give birth to a single pup in June or July. Birth dates are dependent on weather conditions and local climate. For example, after cold winters bats will give birth later than in a normal year. Pups remain in the colony and nurse until they are weaned at approximately 26 days. Pups begin to fly at approximately 21 days. Short periods of torpor (inactivity and reduced metabolic rate) may be used to conserve energy; however, this leaves the bat vulnerable to predators. Even pregnant and lactating females will use short bouts of torpor to reduce energetic expenditure during pregnancy and lactation.

ROOSTS

Roosts are likely selected for safety from predators and heat conservation. The energy budget of Little Brown Bats, particularly when pregnant or lactating is critical to productivity. Heat is an important factor in vigour and growth of nursing pups. A larger cavity permits a greater number of bats to roost together, enabling social thermoregulation (Olson and Barclay 2013). Tree roosts often occur in Balsam Poplar and Trembling Aspen in Saskatchewan. These tree species are susceptible to heart rot fungus that results in the formation of hollow cavities in the interior of the tree. Cracks and crevices in the bark as well as holes made by woodpeckers may also be used as roosts, or function as entrances to the cavities. Balsam Poplar may be important in a forested stand to provide larger roost sites, which may influence the survivorship of bats during parturition (giving birth to young) when they are most vulnerable.

Tree stand age may be important because trees affected by heart rot are usually older or larger. Because trees with heart rot will eventually fall down, rendering cavity roosts unusable by bats, wooded areas need both live and dead trees in varied age classes and states of decay so that suitable roosts are continually being replaced. Studies in a riparian cottonwood forest demonstrated no difference in use of mature (mean age ~60 years) and old (mean age ~105 years) trees and both were used more than young stands (~22 years) by cavity-roosting bats (Swystun *et al.,* 2009).

Males and non-reproducing females roost apart from maternity colonies and individuals are sometimes found roosting during the day on walls of buildings, over 2 m aboveground and often under eaves. They do not necessarily return to the same roost daily.

PREY

Little Brown Bats are insectivorous and hunt on the wing, although they will sometimes glean spiders and other arthropods from surfaces. Prey items are 4-10 mm long and are dominated by Diptera (mainly chironomids), Coleoptera, Lepidoptera, Homoptera, Hymenoptera, and Trichoptera. A Canada-wide study, using genetic markers to determine the broad foraging niche that Little Brown Bat uses, found 45% of their diet was composed of Lepidoptera; 34% Diptera; 11% Ephemeroptera; 6% Trichoptera; and 4% Coleoptera. In Saskatchewan (southwest SK site), the most common prey were two species of chironomid (Clare *et al.*, 2013). Little Brown Bats generally use aerial hawking as a strategy, rather than gleaning prey from surfaces.

Foraging takes place over water or forests, in canopy openings, in riparian areas and other areas where insects congregate. Generally, habitat selection for foraging depends on insect prey availability and the ease with which the bats are able to move through a site. Shelter from wind and avoidance of certain types of noise also influence habitat selection.

BUILDINGS

In higher elevation sites (Yellowstone National Park), female Little Brown Bats used buildings 84% of the time because these sites provided warmer roosts more amenable to reproduction than the rock and tree roosts that were chosen by the male bats (Johnson *et al*., 2019). In Alberta, Little Brown Bats commonly roost in buildings. Buildings provide larger, warmer roosts that enable larger colonies (and thus advantages for thermoregulation).

SUMMER RANGE EXTENT

Summer range includes roost locations, maternity colonies and foraging habitat, and is highly variable, depending on location. Reported home range sizes for Little Brown Bat range from 45 ha to 1600 ha. The main influence on summer range size is likely the distance between high quality roosting sites and high quality foraging sites. Home range size varies through the season for female bats, depending on the development stage of their pups. Between pregnancy and lactation, home range size and flight distance decrease substantially. Females rarely return to the roosts during the night, except during lactation when they return once or twice a night to feed their pups. This lactation period often coincides with periods of high insect abundance, enabling lactating mothers to access sufficient prey in a smaller home range. During lactation, mother bats must increase their food intake by as much as 45% (Anthony and Kunz, 1977).

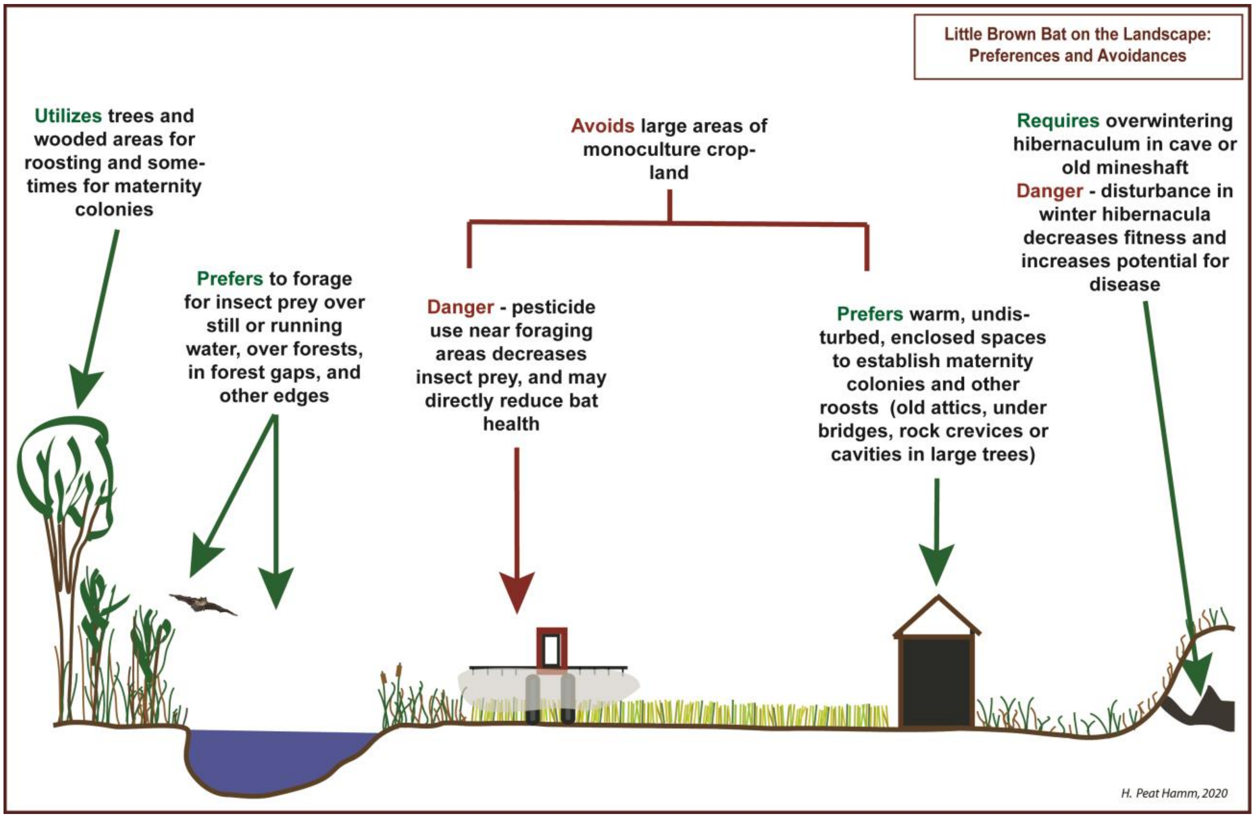


Figure 2. Habitat Diagram for Little Brown Bat (Peat Hamm, H. 2020).

THREATS TO LITTLE BROWN BAT IN CANADA

Little Brown Bat may be the most common bat species in Saskatchewan. However, there is little data regarding population size of Little Brown Bats or existence of hibernacula. At present, the overriding threat is White-nose Syndrome, followed by loss of both anthropogenic and natural habitat.

WHITE-NOSE SYNDROME

White-nose Syndrome is caused by a fungus *Pseudogymnoascus destructans* that was first identified in North America in 2006 in the state of New York. The fungus has been moving westward since then, devastating bat populations in their winter hibernacula. This threat has the potential to amplify all other threats that impact the fitness with which Little Brown Bats enter their hibernation period.

White-nose Syndrome is caused by cold-loving fungus that invades the skin of muzzles, ears and wings of Little Brown Bats during hibernation. (Brownlee-Bouboulis and Reeder, 2013). The Little Brown Bat is affected more than some bat species because of the species' need for humid hibernacula (Dzal *et al*., 2011). Infection by *Pseudogymnoascus destructans* causes bats to more frequently arouse from hibernation, and each arousal causes them to expend substantial energy rewarming their body. Reduced immunity and increased inflammation responses to the fungus have also been demonstrated (Lilley *et al*., 2016).

Early studies on the spread of White-nose Syndrome indicate that mortality rates are largely dependent on hibernation colony location and size, with larger colonies being affected sooner (Wilder *et al.*, 2011).

Females use fat more slowly than males during torpor and thus may be more likely to survive disturbance by White-nose Syndrome; however, the likelihood of successful reproduction upon emergence is decreased (Jonasson and Willis, 2011). Increase in arousal frequency by White-nose Syndrome explains 58% of morbidity due to *Pseudogymnoascus destructans*, due to depletion of fat stores (Lilley *et al*., 2016). Studies have shown persistence of females despite exposure to White-nose Syndrome (Dobony *et al*., 2011). Evidence of healing of wing damage as well as signs of reproduction was documented, indicating it is possible to recover from White-nose Syndrome, but also that some females partitioned energy into healing enough to preclude reproduction. Some recaptured females were apparently able to survive repeated exposure and damage from White-nose Syndrome (Dobony *et al*., 2011).

HABITAT LOSS AND DEGRADATION

Activities that destroy wetlands or waterways or that remove old growth Balsam Poplar and Trembling Aspen trees are deleterious to the abundance and productivity of Little Brown Bat.

Ephemeral ponds are important for foraging habitat in dryland sites and loss of these wetlands is overlooked when estimating habitat loss (Korine *et al.*, 2016). Destruction of ephemeral wetlands may make sites unusable for Little Brown Bats. Most often, the removal of ephemeral ponds includes removal of the encircling trees, which might otherwise provide roosts for Little Brown Bats.

Increasingly, older perimeter windbreaks are being removed and old farm sites are cleared. These trees and buildings (see below) may be providing roosting habitat for bats.

MANAGEMENT OF ANTHROPOGENIC STRUCTURES

Removal of buildings, eviction or eradication of bats from buildings may have a large negative impact on the colony.

Buildings and bridges are often used as roosts during summer. Maternity colonies may be established in attics and walls of occupied and unoccupied buildings. Females typically return to the site from which they were born. Therefore, disruption of a maternity colony will have a disruptive effect on present and future generations of Little Brown Bats reared at these sites. It has been recorded that maternity colony sites may be abandoned after site destruction even when alternatives, such as a bat box, are provided in the area. Additionally, if bats are killed, it can take decades for colonies to recover to previous population levels.

INSECTICIDES

Insecticides sprayed on crops or forests, drenched on soil or applied to agricultural crop seeds have the potential to negatively affect insect prey of bats. Little Brown Bats may be susceptible to indirect negative effects through the trophic cascade.

Any insecticides, whether sprayed on crops or forests or soil drenched, have the potential to kill insects that are prey of bats. *Bacillus thuringiensis* (BT/BTK), a biological form of insect control also kills insects that are prey of bats. Insecticides not only reduce the amount of prey available to bats, but ingestion of insects that have been exposed to insecticides but have not died, may impact bat behavior and/or reproductive success.

Bats may be more vulnerable than non-flying mammals to the toxic effects of contaminants as they have relatively short intestinal tracts and greater permeability of intestinal tissues (Caviedes-Vidal *et al*., 2007). As they are longer-lived than many mammals, have a higher metabolism and depend solely on insects and spiders for their diet, their exposure to toxic contaminants is greater. Pesticides may also accumulate in the fat tissue of bats (Fenton 1983, Schober and

Grimmberger 1993) and cross the placenta into developing embryos (Thies 1993; Thies and McBee 1994).

Recently, systemic insecticides, such as neonicotinoids, have received considerable attention as a threat to insect survival. Neonicotinoids were introduced in the 1990s, and are represented in various farm and garden products in the chemicals imidacloprid, dinotefuran, clothianidin, and thiamethoxam.

Neonicotinoids applied to crop seeds are non-selective and are toxic to non-target, beneficial insects. Neonicotinoids insecticides have been demonstrated to be persistent in water and negatively affect aquatic species that are prey of bats. They are likely to reduce populations of invertebrates found in ephemeral ponds (Samson-Robert et al. 2014). Specifically, populations of Chironomids (Diptera) and Ostracoda have been shown to be negatively affected by field level doses of some neonicotinoids (Basley and Goulson, 2018).

A review in 2017 stated that are no studies have measured the effect of neonicotinoids on bats and bat populations (Wood and Goulson, 2017). They state that studies on butterflies have demonstrated negative impacts of neonicotinoids and, given the similarity of moths to butterflies, the assumption is that moths would have similar negative reactions. Because bats consume moths, reduction in prey or sublethal doses in prey could be affecting bat populations. The neonicotinoid (imidacloprid) has been demonstrated to have a negative impact on spatial memory via neural apoptosis in an echolocating bat (*Hipposideros terasensis*).

DISTURBANCE OF HIBERNACULA

Disturbance of hibernacula by humans represents two separate potential threats; actual disturbance of torpor; and contamination of the hibernacula.

Disturbance of bats during the winter may cause them to emerge from hibernation, resulting in wasted energy and potentially lower overwinter survival. Accessing hibernacula at any time of year, leads to a risk of introducing the fungus that causes White-nose Syndrome, *Pseudogymnoascus destructans.* In some cases efforts to physically block human access to hibernacula in summer have caused increased incidence of fungal spread and growth, so physical blockage of access may be detrimental.

PREDATORS

Predators, particularly in human-modified landscapes, can impact bat populations.

Domestic cats, raccoons, corvids, owls, snakes, rodents and frogs have been noted to prey on bats, although no particular predator is noted to single out bats as prey. Many of these predators are associated with human-modified landscapes such as farmyards.

When bats choose exposed roosts on walls of buildings, they are typically >2m above ground and often under overhanging roof or other structure which may provide some protection from predation. However, height of roosts will not ensure safety from predators. Domestic cats are able to catch bats in flight when they swoop down out of a roost.

CLIMATE CHANGE

Drought may indirectly impact Little Brown Bats by concurrent decline in prey insects.

The bat species most susceptible to negative effects of climate change will be those residing in geographic areas predicted to become drought stressed (Sherwin *et al*., 2013). The prairie region of the range of Little Brown Bats falls within this category according to some climate change models. The loss of ephemeral ponds during periods of drought will reduce the supply of drinking water and negatively impact aquatic insect populations and thus decrease food for Little Brown Bats. Additionally, Little Brown Bat cannot cope with excess heat, and extended periods of increased temperatures could have a significant impact.

OTHER

Roads may pose a threat to bats through vehicle strikes, lights, vibration or noise.

Little Brown Bats may be killed on busy roads by vehicle strikes. Bats rely heavily on echolocation for prey detection and orientation, and thus there is potential for noise from busy roads to interfere. Little Brown Bats are relatively tolerant of light, and may be attracted to lights on a road to hunt insects. On logging roads, just the vibration from logging trucks could disturb a hibernaculum.

Noise in certain broadband ranges and some types of artificial light can impact foraging and productivity.

Noise that impacts bats in general is broadband noise within the range of 10-100 kHz and greater than 50 dB. Little Brown Bat is likely impacted by broadband noise within the range of 10-100 kHz and greater than 80 dB. More information specific to noise impacts to Little Brown Bat is needed, however it is possible that such noise sources as compressor stations, pump jacks and construction traffic may negatively affect them. There is evidence that some bat species avoid traffic noise, but this is unknown for Little Brown Bat. Further complicating the impacts of noise, is the possibility that frequent exposure to the same noise may reduce bat sensitivity to that noise.

Because bats forage nocturnally, artificial light sources can have negative effects. Little Brown Bats are relatively tolerant of artificial light sources and will hunt insects attracted to light. Hunting in lights may make bats more susceptible to being captured by predators such as owls. Artificial light can reduce insect abundance if insects deplete their energy flying around lights. Lights shining on a roost can delay emergence, as the bat thinks it is still daytime. As a result foraging time is reduced and productivity may decline as bat health is impacted.

Mortality due to wind turbines results from both direct impacts with blades, and barotrauma (due to effect of turbine movement on local air pressure).

Wind turbines are a bigger issue for long distance migrant bat species than for regional migrants such as the Little Brown Bat. The largest effect of wind turbines on Little Brown Bats occurs during local migrations in spring and fall between hibernacula/swarming sites and summer foraging grounds/maternity colonies/roosting sites. In summer while foraging, bats do not generally fly at the height of the turbines. Wind turbines sited in open areas are generally safer for Little Brown Bats than turbines within or near trees or forest.

Stock water troughs or rain barrels that are partially full of water may present a trap.

Bats may attempt to drink from water troughs while in flight, but may fall in if they encounter obstacles. Bats may drown if the water level is below the top of the container, and the sides are too smooth for their claws to grip.

HABITAT REQUIREMENTS OF LITTLE BROWN BAT IN SASKATCHEWAN

Little Brown Bats emerge from winter hibernacula around May, migrate to their summer range and the females establish maternity colonies. Pups are born in June-July. Peak lactation is a taxing period for breeding females as their energy requirements are much higher because of the need to grow a fetus, produce milk and periodically return to the roost to feed the pups. Pups are generally flying and foraging by late July. As insect populations decline in fall, bats return to their winter range, swarm and mate, and then re-enter their hibernaculum to overwinter.

The critical dates related to the various habitats required by Little Brown Bat are listed in Table 1.

Table 1. Critical dates of habitat use by Little Brown Bat in Saskatchewan.

Life Stage	Critical dates for Little Brown Bats in Saskatchewan
Emergence from winter hibernacula	• Late April to early June • Females emerged before males in MB study - females early May, males late May • Females in better shape (body fat) emerge earlier than those that are not. • Move to summer habitat or maternity colony sites – the time between emergence and arriving in maternity colonies can take up to 6 weeks
Brood-rearing	• Pups born early June to late July (earlier in warmer areas of the province) • Pups weaned at ~26 days - during lactation, females need close access to foraging areas to be able to return and feed pups.
Foraging	• Males migrate and roost in separate locations from maternity colonies, spending their entire summer in foraging habitat. • Key foraging period for females is during lactation when time is a constraint (need to feed pups between foraging trips). Critical time to have good prey biomass available. • Key foraging period for males is late summer when they produce mature sperm cells requiring high energy. • Flying juveniles emerge mid-July to August.
Swarming	• Begin moving to hibernacula • Late summer/fall (August), prior to settling into hibernacula - individuals may swarm at sites different from the hibernation site. • Breeding occurs during this period
Re-enter winter hibernacula	• September - October

HABITAT FEATURES IMPORTANT TO LITTLE BROWN BATS

Little Brown Bat is a regional migrant that moves up to several hundred kilometers between overwintering hibernacula and summer habitat. Although the location of only a small fraction of hibernacula are known, many of these bats have been documented travelling hundreds of kilometers (up to 600 km or more) between summer and winter habitat.

OVERWINTERING

Little is known about where Little Brown Bats that summer in Saskatchewan overwinter. In North Dakota, Little Brown Bat hibernacula include rock crevices and caves in badlands. Caves and abandoned mines are known to house overwintering Little Brown Bats elsewhere, but even these known hibernacula only account for a small percentage of the millions of Little Brown Bats that summer in western Canada.

Little Brown Bats rarely overwinter in anthropogenic structures. The presence of bat guano indicates that bats are using a structure during their active season, not during hibernation. Buildings that are suitable for summer habitat rarely provide the temperature and humidity requirements for overwintering Little Brown Bats.

From known hibernacula outside Saskatchewan, we know that the main overwintering habitat requirements include high relative humidity (≥ 90%) and a consistent temperature in the range of 0 – 13^{o}C. Known hibernacula have a single entrance with a temperature gradient between the interior of the hibernacula and the exterior. During winter, hibernacula are warmer than outside temperatures and are cooler in summer. Little Brown Bats are found in the portion of the hibernacula where air flow is the lowest, ensuring consistent temperature and humidity.

Preferred overwintering (hibernacula) habitat features are:

- Caves, abandoned mines, rock crevices
- Consistent temperature overwinter in the range of 0 – 13^{o}C
- Relative humidity ≥ 90%

EMERGENCE AND MIGRATION

Female bats emerge from hibernation and may stay in close proximity to the hibernacula for up to six weeks before moving to summer habitat. Little is known about their habitat requirements during this period or during migration to summering habitat.

In southern Manitoba, the documented range of seasonal movement from hibernacula to summer habitat was 10 to 647 km (Norquay *et al*., 2013). Little Brown Bats tend to have high fidelity to both hibernacula and summer sites. Only a small percentage of individuals changed sites between years, relocating a median distance of 315 km, with a fifth of them moving more than 500 km to change sites. Norquay *et al*. (2013) also found that females were more likely to relocate than males.

Little Brown Bats return in the spring to the site where they were born/weaned. It is not known what routes Little Brown Bats take between hibernacula and summer habitat, and therefore no information exists on barriers to migration.

MATERNITY COLONIES AND ROOSTS

Little Brown Bats require sheltered places to raise pups (maternity colonies) and places to rest when not foraging. These sites are called roosts and vary from cavities in trees to anthropogenic structures such as bridges and buildings. They may even use sheltered topography such as ridges or rock outcrops. Maternity roost locations may differ from other types of roosts, and night roosts may differ from daytime roosts. Day roosts used for resting are often cooler locations that may be used by single or multiple bats. These tend to be opportunistic and may simply include shaded, secluded locations such as crevices in trees, expansion joints in concrete bridges or even roof overhangs. Maternity roosts and night roosts used for resting are more strategic, requiring enough space for multiple bats, restricted air flow for thermoregulation, and shelter from weather.

In grassland ecoregions, roosts include bridges, rock crevices, buildings, and trees in towns, farms, graveyards, and possibly shelterbelts. Buildings known to be used as roosts by Little Brown Bats include occupied and abandoned houses, cottages, sheds and barns. In forested ecoregions, roosts are primarily deciduous trees with cavities. However, Little Brown Bats also use buildings for roosts in forested areas. Some research indicates that they may prefer roosting in buildings over trees, but little is known about how or why they select one type of roost over another.

Tree cavities supporting Little Brown Bat in Saskatchewan have been found primarily in trembling Aspen and balsam Poplar trees. Often over 100 individual Little Brown Bats squeeze into a single cavity, probably to maintain body temperatures. The size of the cavity opening is thought to be more important than the size of the cavity. Smaller openings, just large enough for bats to enter (i.e., 2-3 cm in diameter), may be preferred to reduce the risk of predators accessing the roost. These openings are often cracks in the shell of the tree or sometimes holes made by woodpeckers.

Cavity entrances in trees or chamber entrances for roosts in anthropogenic structures of rock crevices are ideally at least 2 m above ground level. Little Brown Bats in Saskatchewan sometimes use entrances as low as 1.5 m, but this height increases the risk of being caught by predators such as cats when exiting or entering the roost.

In anthropogenic settings, trees must be old enough to support cavities. This requirement is also true for natural or managed forest. Trees of this type primarily occur in mature or old growth forest stands.

Little Brown Bats will use multiple roosts during the summer season. It is therefore important in forested areas to ensure that stands of mature or old growth mixedwood or deciduous trees exist that are large enough to supply numerous roost trees. Bats may use multiple roosts for several reasons including having backup roost locations to replace roost trees that fall down, moving between roosts so they are not as readily located by predators, and/or to keep parasite loads low.

In terms of location of roosts, the roost trees of cavity-roosting bat species have been documented to be closer to water and in more open canopy areas than random trees.

Preferred summer roosting habitat features are:

- Roosting sites - trees, bridges, rock crevices, buildings, bat houses.
- Full sun on the roost to keep it warm.
- Maternity roosts – buildings or large, well-protected trees with cavities or large crevices.
- Where tree cavities are used - forest stand of sufficient age to have larger cavities and to have recruitment of new trees to age and replace as old trees fall.
- Old trees within the stand for roosting and/or maternity colony.
- Multiple roosts
- Still water or watercourse nearby.

FORAGING HABITAT

The existence of water bodies, either still water or moving, are the best predictors of active season habitat selected by Little Brown Bat. Weather impacts on insect populations have a strong but indirect effect on habitat use. Bats favour warm, low wind evenings for foraging.

Little Brown Bats are known to be less common in badlands and on ecosites with Solonetzic soils in Alberta (Showalter *et al*., 1979). In southern Saskatchewan, it is likely that Little Brown Bats are most common in the Boreal Transition, Aspen Parkland and Cypress Uplands ecoregions, followed by the Mixedgrass Ecoregion, and least common in the Semiarid Mixedgrass Ecoregion during summer.

When Little Brown Bats emerge from spending the day in a warm roost, they have gone about 14 hours without food or water. In the boreal forest of Saskatchewan they may spend even longer hours in the roost when the summer day length is longer. Waterbodies, especially still water, are important in relatively close proximity to the roost (within 2 km) to provide drinking water for bats. Water for drinking is most important for females who would have higher water requirements while lactating.

Bats drink on the wing and therefore require a water source with no obstructions to flying. Drinking water sources may include standing portions of slow flowing waterbodies, any still waterbody, and even troughs or rain barrels. Steep banks around small waterbodies or troughs and rain barrels that are only partially full of water may prevent the bat from flying away from the water source.

Little Brown Bats will commonly fly 6 to 8 km from their roosts to forage. They prefer to forage where insects are most abundant at dusk and at night. Preferred foraging habitat is often over water or in riparian areas. In grassland ecoregions, Little Brown Bats prefer natural grasslands over tame pastures. In forested ecoregions in Saskatchewan, mixedwood forests of spruce, Aspen and balsam Poplar were used more for hunting than deciduous forests, although both were used

(Kalcounis *et al*., 1999). Cropland may be used during insect outbreaks, but otherwise it is mainly avoided.

Insects are sometimes more common at structural edges between vegetation types. Little Brown Bat will forage on the edge of trees, between cropland and permanent cover, beside roads and trails. However, they also forage above trees and water, and will forage within open forests.

Because bats forage nocturnally, artificial light sources can have negative effects. Little Brown Bat is tolerant of artificial light sources and will hunt insects attracted to light. Bats flying across roads are susceptible to vehicle strikes. Hunting in lights may make bats more susceptible to being captured by predators such as owls. Artificial light can also reduce insect abundance if insects deplete their energy flying around lights. This, combined with possible delayed emergence from roosts, may result in reduced foraging time and reduced productivity as bat health is impacted.

Noise can degrade foraging habitat for bats by impairing their ability to forage and by causing them to avoid noisy areas. Noise that impacts Little Brown Bats is thought to be broadband noise within the range of 10-100 kHz and greater than 80dB. However, research on the effects of noise from natural gas air compressors has shown no change in activity levels by Little Brown Bat (Bunkley *et al*., 2015).

Preferred foraging habitat features are:

- Water bodies, especially those sheltered from wind
- Natural grasslands
- Mixed wood and deciduous forests
- Riparian areas
- Natural light/dark (i.e., no artificial light sources)

Optimal habitat targets are listed in Table 2. Many of these habitat targets may be affected by management.

Table 2. Optimal habitat targets for Little Brown Bat in seasonal habitats.

<table>
<tr><th>SEASONAL HABITAT FEATURE</th><th>HABITAT FEATURE</th><th colspan="2">HABITAT TARGET</th></tr>
<tr><td>Overwintering</td><td>Hibernacula</td><td colspan="2">Rock crevices, caves or abandoned mines; internal temperatures between 0 and 13°C; humidity ≥90%</td></tr>
<tr><td colspan="2">Summer Home Range Size</td><td colspan="2">Variable, but can be quite large – up to several thousand ha. Commonly travel 6 – 8 km from summer roosts when foraging.</td></tr>
<tr><td colspan="2"></td><td>Grassland Ecoregions</td><td>Forest Ecoregions</td></tr>
<tr><td rowspan="7">Summer Roosts</td><td rowspan="2">Woody vegetation</td><td>Woody vegetation is not critical in grassland ecoregions, but is used if available. Deciduous trees (Trembling Aspen, Balsam Poplar and other cottonwoods) in towns, farmyards, graveyards, etc. old enough to support roosting cavities</td><td>Trees such as Balsam Poplar and Trembling Aspen with advanced heart rot creating hollow space inside the tree trunk</td></tr>
<tr><td colspan="2">Optimal # of roosts available: ≥ 10
Suboptimal # of roosts: 5-10</td></tr>
<tr><td rowspan="2">Cavity or chamber entrances</td><td colspan="2">Very small openings to roosting cavities. Not larger than about 3 cm in diameter.</td></tr>
<tr><td colspan="2">Optimal: > 2 m above ground level
Suboptimal: 1.5 – 2 m above ground level</td></tr>
<tr><td>Other natural roost locations</td><td colspan="2">Rock crevices, possibly rock outcrops</td></tr>
<tr><td>Anthropogenic structures</td><td colspan="2">Buildings (occupied or unoccupied), bridges and bat houses</td></tr>
<tr><td>Exposure</td><td colspan="2">Full sunlight on roosts</td></tr>
<tr><td rowspan="7">Foraging</td><td rowspan="5">Water bodies</td><td colspan="2">Permanent still waterbodies or slow moving watercourses within about 2 km of summer roosts</td></tr>
<tr><td colspan="2">At minimum 3m long by 1 m wide</td></tr>
<tr><td colspan="2">Free of emergent vegetation and surface debris</td></tr>
<tr><td colspan="2">Free from obstacles such as fences</td></tr>
<tr><td colspan="2">Sheltered from wind</td></tr>
<tr><td>Land cover (Landscape scale)</td><td>Optimal: Native grassland
Suboptimal: Tame pasture</td><td>Optimal: Mixed wood forests (White spruce, Trembling Aspen, Balsam Poplar)
Suboptimal: Deciduous forests</td></tr>
<tr><td>Habitat types (Site scale)</td><td colspan="2">Optimal: Riparian areas and water
Suboptimal: Forest openings, transitions between land cover</td></tr>
</table>

		types, shelterbelts, fencerows, roadsides and other structural vegetation edges.
	Vegetation buffers	≥200 m of perennial vegetation from crop or forest treated with insecticide (including neonicotinoids and biological control agents)
	Artificial light sources	Optimal: Free of artificial light sources, especially those that shine throughout the night. Suboptimal: lights within the yellow spectrum, fixtures that direct light downward and reduce light spillage, timer controlled light.
	Distance to highways and active logging haul roads	≥ 200 m from foraging area to minimize light and noise disturbance and dust ≥2 km from maternity roosts and other primary roosts
	Distance to industrial infrastructure	≥ 200 m from foraging area or roosts to minimize light and noise disturbance

OTHER RECOMMENDED MANAGEMENT PRACTICES FOR LITTLE BROWN BAT

There are a few management issues unrelated to habitat characteristics impacted by land management that should be taken into consideration when managing for Little Brown Bat. These beneficial management practices are:

- When evicting Little Brown Bats from buildings or other known roosts, wear protective equipment to avoid being bitten or contracting diseases, and follow guidelines in *Managing Bats in Buildings* provided by www.albertabats.ca/resources.
- Practice care in removing old buildings. Follow guidelines in *Managing Bats in Buildings* provided by www.albertabats.ca/resources.
- If renovating buildings, wait until bats are absent before sealing places where bats enter and exit buildings. For more information, see *Managing Bats in Buildings* provided by www.albertabats.ca/resources.
- If using stock watering troughs or rain barrels, ensure they remain full throughout the growing season. For bat friendly dugouts, retention ponds, water troughs and rain barrels, follow guidelines provided by www.albertabats.ca/resources, Multisar: http://multisar.ca/wp-content/uploads/2015/10/Multisar-Bat-BMP-Report-Final.pdf and/or Water for Wildlife: https://www.fs.fed.us/pnw/lwm/aem/docs/olson/bciwaterforwildlife.pdf
- Bat houses or artificial roosts should not be erected in natural habitat but may be beneficial in human-modified landscapes such as farm yards, towns, graveyards etc. In natural habitat, bat houses for Little Brown Bat can negatively impact other bat species. When erecting bat houses, the quality of the roost and the location are critical. Follow guidelines in *Building Homes for Bats* and *Managing Bats in Buildings* provided by www.albertabats.ca/resources.
- Avoid the use of insecticides or seeding of neonicotinoid-treated seeds within 200 metres of water bodies.
- Keep loud developments that produce broadband noise within the range of 10-100 kHz and greater than 80 dB, 200 metres or more away from identified Little Brown Bat foraging habitats.
- Avoid the use of artificial light sources near roosts or hibernacula. If it is necessary to use artificial light follow guidelines in *Building Bat-Friendly Communities* provided by www.albertabats.ca/resources or see Bat Conservation Trust http://www.bats.org.uk/pages/bats_and_lighting.html
- Avoid placing wind turbines near known hibernacula or maternity colonies. For guidance on siting and construction of wind turbines, see *Best Management Practices Guidelines for Bats in British Columbia* provided by the B.C. Ministry of Environment: http://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12460, and siting guidelines for Saskatchewan: https://www.saskatchewan.ca/-/media/news-release-backgrounders/2016/sept/wind-siting-guide.pdf
- Light, noise, dust and smoke can all cause abandonment of roosts. Many industrial activities can produce these stressors, such as the petroleum, forest, mining and transportation industries. Even prescribed burning for conservation purposes may

negatively impact bats. See guidelines for industry developed by the B.C. Ministry of Environment http://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12460

INFORMATION GAPS

No hibernacula housing Little Brown Bats have been reported for Saskatchewan. Tagging and tracking research is necessary to determine where bats that summer in Saskatchewan go to overwinter. Many caves and abandoned mines exist in Saskatchewan, especially in the boreal forest. Surveys of these sites would determine if bats are overwintering there.

Because overwintering locations for Little Brown Bats summering in Saskatchewan are not known, information is lacking on migration routes and associated habitat requirements between summer ranges and wintering sites. Information is also needed on what barriers to migration might exist.

The response of Little Brown Bat to sources of artificial light is a knowledge gap. Little Brown Bat are relatively tolerant of light and may forage in areas with artificial lights to their detriment. Systematic studies of Little Brown Bat with different types of lighting at different locations and times are necessary to determine how sensitive this species is to artificial light.

The effectiveness of recommended set-back distances for noise, roads, insecticides, etc., is not well understood. In fact, Little Brown Bat may be relatively tolerant of certain types of noise. Research on stress levels and productivity related to these impacts would help ensure set-back thresholds can be identified that truly limit negative effects on Little Brown Bats.

ENVIRONMENTAL BENEFIT INDEX FOR LITTLE BROWN BAT HABITAT

CRITERIA AND SCORING

The Environmental Benefit Index (EBI) was developed by compiling comprehensive categories of criteria based on available knowledge, such as Little Brown Bat population and habitat research, expert opinion, and species recovery documents.

The EBI begins with three screening criteria. These criteria are either met, in which case the user continues to the next criterion, or not met, in which case the property or potential project is eliminated from further consideration. The remaining criteria are grouped into landscape and site scale habitat features.

A scoring system was devised for the EBI. Each criterion is weighted out of 300, 200, or 100 based on relative importance to the species.

The total scores are calculated based on the following formula:

EBI = ((1)[(2.1+2.2)+(3.1+3.2+3.3+3.4+3.5)+4])
where the numbers refer to sections below.

The EBI result may then be divided by the costs of the proposed project or the bid for the project to determine cost-effectiveness. The cost to achieve the habitat requirements could include added management, added infrastructure or inputs, or lost opportunities.

The range of possible scores for candidates that pass the screening criteria is quite wide. The lowest possible total score is 0 and the highest possible score is 1500. When evaluating candidate properties for a project or program, it may be possible to divide the scores into more general High, Moderate, and Low priorities. There are many uses for a general ranking. For example, a more general ranking could be used to determine the total cost of implementing results-based programming on all high-priority sites.

SCREENING CRITERIA FOR ALL HABITAT TYPES

1. Suitable waterbodies for drinking and foraging exist on or within 2 km of the area of consideration.

Yes=1, No=0.

CRITERIA FOR OVERWINTERING (HIBERNACULA)

There are no known locations of Little Brown Bat hibernacula in Saskatchewan, although a substantial amount of work tracking tagged bats and surveying potential hibernacula remains to be done. Therefore, at this point in time no criteria have been established for overwintering habitat for the EBI.

CRITERIA FOR EMERGENCE AND MIGRATION

Information is limited on habitat requirements during the breeding period following emergence and during migration to summer habitat. Therefore, at this point in time no criteria have been established for overwintering habitat for the EBI.

CRITERIA FOR MATERNITY COLONIES AND ROOSTS

2.1. Suitable natural roosts in either grassland or forest ecoregions primarily include older deciduous trees such as balsam Poplar or trembling Aspen with sufficient heart rot to provide cavities as roosts. Cavity entrances will primarily be cracks or splits in the shell of the tree, but may also be openings caused by woodpeckers and sloughing bark. Openings are ideally very small (less than about 3 cm in diameter), likely to prevent access by predators and/or to prevent air flow from cooling the interior of the cavity.

A single bat colony will use numerous roosts during the summer season. Boyles and Robbins (2006) found that a colony of evening bats used 39 different tree roosts in one summer. In older forests, numerous roosts may be available in a fairly localized area. However, in grassland ecoregions, tree roosts are more likely to be far apart, increasing the size of the home range. Little Brown Bat colonies may have a fission-fusion social structure requiring colonies to have a few main roosts and numerous satellite roosts. A Big Brown Bat colony in the Cypress Hills in Saskatchewan was shown to have three main or “nodal” roosts and up to 20-30 additional satellite roosts (Metheny *et al.*, 2007).

Other natural roosts may include rock crevices or rock outcrops. However, as these have not been reported for Saskatchewan no criteria have been included in the EBI.

Higher quality roosts receive full sun during part of the day.

Criteria are presented for both forest and grassland ecoregions. Choose the appropriate criteria for the ecoregion being evaluated. Do not use both.

(Max 300 points)

Suitable Natural Roost Sites – Forest Ecoregions

300	≥ 10 deciduous trees such as balsam Poplar or trembling Aspen with advanced heart rot providing suitable roost cavities within the area of consideration AND cavity entrances not larger than about 3 cm in diameter AND full sun on roosts for part of the day
150	5 - 10 deciduous trees such as balsam Poplar or trembling Aspen with advanced heart rot providing suitable roost cavities within the area of consideration AND cavity entrances not larger than about 3 cm in diameter AND full sun on roosts for part of the day
0	<5 deciduous trees such as balsam Poplar or trembling Aspen with advanced heart rot providing suitable roost cavities within the area of consideration OR cavity entrances all larger than about 3 cm in diameter OR roosts shaded for the entire day

Suitable Natural Roost Sites – Grassland Ecoregions

300	≥ 10 deciduous trees such as balsam Poplar or trembling Aspen with advanced heart rot providing suitable roost cavities within a 5 km radius of the area of consideration AND cavity entrances not larger than about 3 cm in diameter AND full sun on roosts for part of the day
150	2 -10 deciduous trees such as balsam Poplar or trembling Aspen with advanced heart rot providing suitable roost cavities within a 5 km radius of the area of consideration AND cavity entrances not larger than about 3 cm in diameter AND full sun on roosts for part of the day
0	<2 deciduous trees such as balsam Poplar or trembling Aspen with advanced heart rot providing suitable roost cavities within the area of consideration OR cavity entrances all larger than about 3 cm in diameter OR roosts shaded for the entire day

2.2. Natural roost sites may be supplemented by anthropogenic roost sites, or anthropogenic roost sites may be used exclusively regardless of the availability of natural roosts. In grassland ecoregions, anthropogenic structures appear to provide roosts sites in locations where natural roosts would not historically have been present. Higher quality roosts receive full sun during the day or are artificially heated.
(Max 200 points)

Suitable Roost Sites - Anthropogenic

200	Bridges or buildings more than 2 m in height with limited access to the roosting chamber AND heated buildings or full sun on roosts for part of the day OR Multiple high quality bat houses with various sun exposures
100	Bridges, buildings (not heated) more than 2 m in height with limited access to the roosting chamber AND roosts partially shaded during the day OR A single high quality bat house or multiple bat houses with the same sun exposure
0	Bridges or bat houses less than 2 m in height with limited access to the roosting chamber OR roosts shaded for most of the day OR single chamber bat houses

CRITERIA FOR FORAGING HABITAT

3.1. Water sources are an essential part of foraging habitat. Little Brown Bats require a source of drinking water. They drink on the wing by dropping their bottom jaw into the water. Any sized waterbody will suffice for Little Brown Bat, even a small pond. The minimum size for a drinking water source for Little Brown Bat has been estimated at 3 m long by 1 m wide (Bat Conservation International, 2007). Many types of water sources can be suitable including streams, wetlands, dugouts, retention ponds, watering troughs, and even sometimes rain barrels. The water source should be permanent so bats have access to water throughout the active season.

Accessible water bodies are still or slow moving and quiet. Turbulent or fast moving, noisy water is mainly avoided. Accessible water should be free of barriers such as emergent vegetation, surface debris or fences. Bats prefer to access and forage over water that is sheltered from wind. **(Max 300 points)**

Suitable Water Source

300	Permanent wetland or slow moving stream;
150	Dugout or retention pond at least 3m X 1m, free of emergent vegetation and surface debris.
0	Ephemeral water bodies OR dugouts with fences across OR water bodies covered by emergent vegetation or debris

3.2. At a landscape scale in Saskatchewan, Little Brown Bats demonstrate a preference for foraging in native grassland and mixedwood forests comprised of White Spruce, Trembling Aspen, and Balsam Poplar. They will also forage to a lesser extent in tame grasslands and deciduous forest, likely because insect populations are lower or not consistently available. Cropland and coniferous forests appear to be used primarily during insect outbreaks and otherwise are largely avoided for foraging.

At a more localized scale, Little Brown Bats show a strong preference for foraging over water and in riparian areas. They will also forage over, within, and adjacent to forests and along structural edges between vegetation communities such as roadsides, interfaces between cropland and grassland, mowed and unmowed vegetation, etc.

Criteria are presented for both forest and grassland ecoregions. Choose the appropriate criteria for the ecoregion being evaluated. Do not use both.
(Max 200 points)

Land Cover and Habitat Types – Forest Ecoregions

200	Mixedwood forest AND riparian areas
100	Deciduous forest AND riparian areas
50	Coniferous forest OR cropland OR no riparian areas

Land Cover and Habitat Types – Grassland Ecoregions

200	Native grassland AND riparian areas including riparian forests
100	Tame grassland AND riparian areas including riparian forests
50	Cropland OR no riparian areas

3.3. Setback distances from agricultural cropland have been determined for some species to prevent runoff of nutrients, sediments, or pesticides from reducing the quality of habitat. Although no setbacks have been developed for Little Brown Bat to prevent impacts from runoff and drift of pesticides, we have adopted a 200 m setback established for the Monarch Butterfly (SK PCAP, 2020) and Northern Leopard Frog (SK PCAP, 2018a).

For the purposes of this EBI, insecticides include any substance sprayed on cropland or forests, drenched on soil, or planted seeds that have been coated with insecticide. Biological controls such as *Bacillus thuringiensis*, and substances used to control insects in Organic farming are included.
(Max 200 points)

Habitat Quality – Vegetative Buffers

200	≥ 200 m of perennial vegetation between area of consideration and cropland or forest where insecticides (including neonicotinoid coated seeds) are used in the normal course of business
0	Area of consideration adjacent to cropland or forest without a vegetative buffer OR adjacent to other developments where insecticides (including neonicotinoid coated seeds) might be used in the normal course of business

3.4. Little Brown Bat is tolerant of artificial light sources and will hunt insects attracted to light. Hunting in lighted areas where insects congregate may make bats more susceptible to being captured by predators. Artificial light can also reduce insect abundance. Lights shining on a roost can delay emergence, reducing foraging time, and impacting productivity. Certain types of lighting have less impact on bats, and lights that are not on all night have lower impact. **(Max 100 points)**

Habitat Quality – Artificial Light

100	Free of artificial light sources between dusk and dawn.
50	Lights within the yellow spectrum AND fixtures that direct light downward and reduce light spillage AND timer-controlled light.
0	Artificial source of light shining steadily between dusk and dawn

3.5. Roads may pose a threat to bats through vehicle strikes, lights, vibration or noise. The Alberta Community Bat Program recommends keeping loud developments that produce broadband noise within the range of 10-100 kHz and greater than 50 dB, 200m or more away from identified bat foraging habitats. The broadband range estimated to negatively impact Little Brown Bats is within the range of 10-100 kHz and greater than 80 dB As Little Brown Bats commonly fly 6 – 8 km from their roosts when foraging and may be attracted to lights on roads, optimal foraging habitat would have no roads that were busy at night. **(Max 100 points)**

Habitat Quality – Roads

100	No busy roads (Primary & Secondary highways and active log haul roads) within 8 km of area of interest.
50	No busy roads within 2 km of area of interest.
0	Busy road within 2 km of area of interest.

4. Interaction with other species at risk (SAR): Other SAR may exist in the area. The presence of optimal Little Brown Bat habitat may have a positive, negative, or neutral effect on the other SAR found in the area of consideration. For example, the retention of old buildings for bat habitat may provide habitat for avian predators such as Great Horned Owls, which are a substantial threat to Swift Fox, Greater Sage Grouse, and possibly other SAR
(**Max points 100**)

Interaction with other Species at Risk

100	Little Brown Bat habitat contributes positively to other area SAR.
0	Little Brown Bat habitat has no impact on other area SAR.
-100	Little Brown Bat habitat has a negative impact on other area SAR.

EBI = ((1)[(2.1+2.2)+(3.1+3.2+3.3+3.4+3.5)+4])

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