SPECIES STATUS REPORT

Big Brown Bat, Little Brown Myotis, Northern Myotis, Long-eared Myotis, and Long-legged Myotis

(Eptesicus fuscus, Myotis lucifugus, Myotis septentrionalis, Myotis evotis, and Myotis volans)

Dléa det’ǫne (Shúhta/Shíhta Got’įne, Mountaın/K’áalo Got’įne, Délįnę Got’įne, K’ásho Got’įne)

Daatsadh natandit’ee (Gwichyah Gwich’in)

Daatsoo natindit’ee (Teetl’it Gwich’in)

Tsáret’áné (Chıpewyan)

Gútłóolía dlų̨ą det’onı (Kátł’odehche)

Sérotine brune, vespertilion brun, vespertilion nordique, vespertilion à longues oreilles, vespertilion à longues pattes (French)

April 2017

NORTHWEST TERRITORIES SPECIES AT RISK COMMITTEE

DATA DEFICIENT – Big brown bat
SPECIAL CONCERN – Little brown myotis
SPECIAL CONCERN – Northern myotis
DATA DEFICIENT – Long-eared myotis
DATA DEFICIENT – Long-legged myotis

Status of Big Brown Bat, Little Brown Myotis, Northern Myotis, Long-eared Myotis, and Long-legged Myotis in the NWT

Species at Risk Committee status reports are working documents used in assigning the status of species suspected of being at risk in the Northwest Territories (NWT).

Suggested citation:

Species at Risk Committee. 2017. Species Status Report for Big Brown Bat, Little Brown Myotis, Northern Myotis, Long-eared Myotis, and Long-legged Myotis (*Eptesicus fuscus, Myotis lucifugus, Myotis septentrionalis, Myotis evotis, and Myotis volans*) in the Northwest Territories. Species at Risk Committee, Yellowknife, NT.

ISBN: 978-0-7708-0248-6

Production note:

The drafts of this report were prepared by Jesika Reimer and Tracey Gotthardt under contract with the Government of the Northwest Territories, and edited by Claire Singer.

For additional copies contact:

Species at Risk Secretariat
c/o SC6, Department of Environment and Natural Resources
P.O. Box 1320
Yellowknife, NT X1A 2L9
Tel.: (855) 783-4301 (toll free)
Fax.: (867) 873-0293
E-mail: sara@gov.nt.ca
www.nwtspeciesatrisk.ca

ABOUT THE SPECIES AT RISK COMMITTEE

The Species at Risk Committee was established under the *Species at Risk (NWT) Act*. It is an independent committee of experts responsible for assessing the biological status of species at risk in the NWT. The Committee uses the assessments to make recommendations on the listing of species at risk. The Committee uses objective biological criteria in its assessments and does not consider socio-economic factors. Assessments are based on species status reports that include the best available Aboriginal traditional knowledge, community knowledge and scientific knowledge of the species. The status report is approved by the Committee before a species is assessed.

ABOUT THIS REPORT

This species status report is a comprehensive report that compiles and analyzes the best available information on the biological status of the big brown bat, little brown myotis, northern myotis, long-eared myotis, and long-legged myotis in the NWT, as well as existing and potential threats and positive influences. Full guidelines for the preparation of species status reports, including a description of the review process, may be found at www.nwtspeciesatrisk.ca.

Northwest Territories Environment and Natural Resources

Environment and Natural Resources, Government of the Northwest Territories, provides full administrative and financial support to the Species at Risk Committee.

Cover illustration photo credit: Little brown myotis (credit: Joanna Wilson, ENR)

NORTHWEST TERRITORIES SPECIES AT RISK COMMITTEE

Assessment of Big Brown Bat

The Northwest Territories Species at Risk Committee met in Yellowknife, Northwest Territories on November 16, 2016 and assessed the biological status of big brown bats in the Northwest Territories. The assessment results were not released until April 2017 to facilitate the bundling of assessment results with two other species. The assessment was based on this approved status report. The assessment process and objective biological criteria used by the Species at Risk Committee are available at: www.nwtspeciesatrisk.ca.

Assessment: Data deficient in the Northwest Territories

A data deficient species means a species in respect of which the Species at Risk Committee does not have sufficient information to categorize as extinct, extirpated, endangered, threatened, special concern, or not at risk.

Main Factors:

- Little is known about this species in the Northwest Territories. There are few confirmed records of this species occurring in the Northwest Territories, including no confirmed records of reproduction. However, there are indications that the species might be more widely distributed than confirmed records suggest.
- The main threat is:
    - The future impact of white-nose syndrome on this species is uncertain, but there is some concern that white-nose syndrome will have an impact on this species in the Northwest Territories. The big brown bat does not appear to be as susceptible to the negative impacts of white-nose syndrome as little brown myotis and northern myotis. In eastern North America, the effect of white-nose syndrome has resulted in population declines as high as 41%, but other studies suggest less impact.

Positive influences to big brown bats and their habitat:

- Some of the few records of this species in the Northwest Territories occur within Nahanni National Park Reserve and Wood Buffalo National Park.
- A cave management plan is being developed for the known hibernacula in the Northwest Territories.
- Monitoring programs and education initiatives to promote understanding of bats in general in the Northwest Territories can have a positive impact on the species.

Recommendations:

- Additional studies, including traditional knowledge studies, are required for all bat species in the Northwest Territories.
- Complete and implement the Northwest Territories' cave management plan, participate in collaborative research and monitoring on bats and white-nose syndrome in Canada, and help facilitate communication and coordination of bat conservation and monitoring efforts across jurisdictions.
- Promote and implement best management practices to mitigate human impacts on bats and their habitat, including roosting sites.

Assessment of Little Brown Myotis

The Northwest Territories Species at Risk Committee met in Yellowknife, Northwest Territories on November 16, 2016 and assessed the biological status of little brown myotis in the Northwest Territories. The assessment results were not released until April 2017 to facilitate the bundling of assessment results with two other species. The assessment was based on this approved status report. The assessment process and objective biological criteria used by the Species at Risk Committee are available at: www.nwtspeciesatrisk.ca.

Assessment: Special concern in the Northwest Territories

A species of special concern means that the species may become threatened or endangered in the Northwest Territories because of a combination of biological characteristics and identified threats.

Reasons for the assessment: Little brown myotis fit criterion (b) for special concern.

(b) – The species may become threatened if negative factors are neither reversed nor managed effectively.

Main Factors:

- Although the range of this species is fairly large and there are at least a few thousand individuals in the Northwest Territories, there are currently only two known over-wintering sites.
- Although white-nose syndrome is not currently present in the Northwest Territories, it is estimated that at current expansion rates, it could reach our populations from eastern North America in one or two decades. With the recent discovery of white-nose syndrome in the United States' Pacific northwest, it is conceivable that this disease could spread to the Northwest Territories sooner than predicted.
- The main threat is:
    - This species is highly susceptible to devastating population declines as a result of white-nose syndrome. In eastern Canada, populations impacted by white-nose syndrome have declined by 94%.

Additional Factors:

- Human impacts at hibernacula and exclusion and removal of maternity roosts have the potential to affect a large proportion of the species' population at the same time.

Positive influences to little brown myotis and their habitat:

- Some of the records of this species in the Northwest Territories occur within Nahanni National Park Reserve and Wood Buffalo National Park.
- Little brown myotis has been federally listed as endangered under the *Species at Risk Act*, which provides some protection for individuals and habitat in Canada, including the Northwest Territories.
- A cave management plan is being developed for the known hibernacula in the Northwest Territories.
- Monitoring programs and education initiatives to promote understanding of bats in general in the Northwest Territories can have a positive impact on the species.

Recommendations:

- Additional studies, including traditional knowledge studies, are required for all bat species in the Northwest Territories.
- Complete and implement the Northwest Territories' cave management plan, participate in collaborative research and monitoring on bats and white-nose syndrome in Canada, and help facilitate communication and coordination of bat conservation and monitoring efforts across jurisdictions.
- Promote and implement best management practices to mitigate human impacts on bats and their habitat, including roosting sites.

Assessment of Northern Myotis

The Northwest Territories Species at Risk Committee met in Yellowknife, Northwest Territories on November 16, 2016 and assessed the biological status of northern myotis in the Northwest Territories. The assessment results were not released until April 2017 to facilitate the bundling of assessment results with two other species. The assessment was based on this approved status report. The assessment process and objective biological criteria used by the Species at Risk Committee are available at: www.nwtspeciesatrisk.ca.

Assessment: Special concern in the Northwest Territories

A species of special concern means that the species may become threatened or endangered in the Northwest Territories because of a combination of biological characteristics and identified threats.

Reasons for the assessment: Northern myotis fit criterion (b) for special concern.

(b) – The species may become threatened if negative factors are neither reversed nor managed effectively.

Main Factors:

- The range of this species in the Northwest Territories is fairly large. They are suspected to be wintering in the two known hibernacula in the Northwest Territories.
- Although white-nose syndrome is not currently present in the Northwest Territories, it is estimated that at current expansion rates, it could reach our populations from eastern North America in one to two decades. With the recent discovery of white-nose syndrome in the Unites States' Pacific northwest, it is conceivable that this disease could spread to the Northwest Territories sooner than predicted.
- The main threat is:
    - This species is highly susceptible to devastating population declines as a result of white-nose syndrome. In eastern Canada, populations impacted by white-nose syndrome have declined by 94%.

Additional Factors:

- Human impacts at hibernacula and exclusion and removal of maternity roosts have the potential to affect a large proportion of the species' population at the same time.

Positive influences to northern myotis and their habitat:

- Some of the records of this species in the Northwest Territories occur within Nahanni National Park Reserve and Wood Buffalo National Park.

- Northern myotis has been federally listed as endangered under the *Species at Risk Act*, which provides some protection for individuals and habitat in Canada, including the Northwest Territories.
- A cave management plan is being developed for the known hibernacula in the Northwest Territories.
- Monitoring programs and education initiatives to promote understanding of bats in general in the Northwest Territories can have a positive impact on the species.

<u>Recommendations</u>:

- Additional studies, including traditional knowledge studies, are required for all bat species in the Northwest Territories.
- Complete and implement the Northwest Territories' cave management plan, participate in collaborate research and monitoring on bats and white-nose syndrome in Canada, and help facilitate communication and coordination of bat conservaton and monitoring efforts across jurisdictions.
- Promote and implement best management practices to mitigate human impacts on bats and their habitat, including roosting sites.

Assessment of Long-eared Myotis

The Northwest Territories Species at Risk Committee met in Yellowknife, Northwest Territories on November 16, 2016 and assessed the biological status of long-eared myotis in the Northwest Territories. The assessment results were not released until April 2017 to facilitate the bundling of assessment results with two other species. The assessment was based on this approved status report. The assessment process and objective biological criteria used by the Species at Risk Committee are available at: www.nwtspeciesatrisk.ca.

Assessment: Data deficient in the Northwest Territories

A data deficient species means a species in respect of which the Species at Risk Committee does not have sufficient information to categorize as extinct, extirpated, endangered, threatened, special concern, or not at risk.

Main Factors:

- Very little information is known about this species in the Northwest Territories. There is only one confirmed record of this species occurring in the Northwest Territories.
- The main threat is:
    - The future impact of white-nose syndrome on this species is uncertain; however, given the documented devastating impact on other hibernating *Myotis* species, there is concern that white-nose syndrome may have a large impact on this species.

Positive influences to long-eared myotis and their habitat:

- Records for this species in the Northwest Territories are within Nahanni National Park Reserve.
- Monitoring programs and education initiatives to promote understanding of bats in general in the Northwest Territories can have a positive impact on the species.

Recommendations:

- Additional studies, including traditional knowledge studies, are required for all species in the Northwest Territories, with an emphasis on the Liard Valley.
- Complete and implement the Northwest Territories' cave management plan, participate in collaborative research and monitoring on bats and white-nose syndrome in Canada, and help facilitate communication and coordination of bat conservation and monitoring efforts across jurisdictions.

- Promote and implement best management practices to mitigate human impacts on bats and their habitat, including roosting sites.

Assessment of Long-legged Myotis

The Northwest Territories Species at Risk Committee met in Yellowknife, Northwest Territories on November 16, 2016 and assessed the biological status of long-legged myotis in the Northwest Territories. The assessment results were not released until April 2017 to facilitate the bundling of assessment results with two other species. The assessment was based on this approved status report. The assessment process and objective biological criteria used by the Species at Risk Committee are available at: www.nwtspeciesatrisk.ca.

Assessment: Data deficient in the Northwest Territories

A data deficient species means a species in respect of which the Species at Risk Committee does not have sufficient information to categorize as extinct, extirpated, endangered, threatened, special concern, or not at risk.

Main Factors:

- Very little information is known about this species in the Northwest Territories. There are only three confirmed records of this species occurring in the Northwest Territories.
- The main threat is:
    - The future impact of white-nose syndrome on this species is uncertain; however, given the documented devastating impact on other hibernating *Myotis* species, there is concern that white-nose syndrome may have a large impact on this species.

Positive influences to long-legged myotis and their habitat:

- Record for this species in the Northwest Territories are within Nahanni National Park Reserve.
- Monitoring programs and education initiatives to promote understanding of bats in general in the Northwest Territories can have a positive impact on the species.

Recommendations:

- Additional studies, including traditional knowledge studies, are required for all bat species in the Northwest Territories, with an emphasis on the Liard Valley.
- Complete and implement the Northwest Territories' cave management plan, participate in collaborative research and monitoring on bats and white-nose syndrome in Canada, and help facilitate communication and coordination of bat conservation and monitoring efforts across jurisdictions.

- Promote and implement best management practices to mitigate human impacts on bats and their habitat, including roosting sites.

Table of Contents

Executive Summary

Description

At least 7, possibly 8 species of bats are found in the Northwest Territories (NWT): big brown bat (*Eptesicus fuscus*), little brown myotis (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), long-eared myotis (*Myotis evotis*), long-legged myotis (*Myotis volans*), hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*), and likely eastern red bat (*Lasiurus borealis*). This report focuses on the first five species (*Eptesicus* and *Myotis* genera) because they are hibernating species that are at an increased risk for white-nose syndrome (WNS) and, therefore, of conservation concern.

All five bat species of focus in this report are insectivorous species of the family Vespertilionidae. The big brown bat is the largest (14-21 grams (g)), while the four *Myotis* are all small-bodied bats (6-10 g) that vary slightly in size and morphology and are difficult to tell apart. All five species have brown hair and are distinguishable from migratory bats in the territory (hoary, silver-haired and eastern red bat), which all have distinct colouring and are larger in size than the *Myotis* species.

Distribution

Observations are limited to the more southern portion of the NWT. Surveys suggest that the Nahanni region, in the south-west corner of the territory, supports a high diversity of bat species during the summer season. Long-eared and long-legged myotis have been observed in this region only. Big brown bats, and little brown and northern myotis are more widespread in the southern NWT, with known concentrations of large *Myotis* summer maternity roosts and winter hibernacula in the South Slave region.

Biology and Behaviour

The reproductive strategy of the five focus species is sexual reproduction with delayed internal fertilization and live birth of one young (pup) per year. Mating is indiscriminant and promiscuous and occurs primarily in swarms at hibernacula during autumn, prior to hibernation. Females are colonial breeders and become sexually mature their first or second year. Reproductive rates of little brown myotis in the NWT are lower than observed farther south. Studies suggest a mean life expectancy of 5.7 years for the big brown bat (maximum 9-19 years), 6.0-7.0 years for the little brown myotis (max. 34 years), 2.2 years for the long-eared myotis (max. 16-22 years), and 2.1 years for the long-legged myotis (max. 21 years). Mean life expectancy is not reported in the literature for northern myotis, although maximum recorded age for this species is 19 years.

Population

Population sizes and trends are unknown in the NWT. Global population estimates are similarly unavailable for the big brown bat, northern myotis, long-eared myotis, and long-legged myotis, although the population of each species is expected to be greater than 100,000. The global population for little brown myotis was estimated at 6.5 million in 2006; however, this figure does not account for mortalities related to white-nose syndrome.

Habitat

All five species of focus are typically forest dwelling bats that have two primary habitat requirements: (1) summer roost and foraging habitat and (2) winter hibernation sites. Throughout their range they perform annual small-scale migrations between winter hibernacula and summer roosts. During the summer season, all five species typically use natural roosts such as tree cavities, under exfoliating bark, rock crevices, and artificial maternity roosts such as buildings. Reproductive females often congregate in groups called maternity colonies. During winter, all five species hibernate in cool, humid hibernacula such as caves. Habitat availability for bats in the NWT has not been quantified. Important hibernation sites have been identified in areas of karst habitat and further exploration is needed to determine if additional hibernacula exist in the territory.

Threats and limiting factors

The most serious threat to the bat species of interest is white-nose syndrome (WNS), which currently affects big brown bats, little brown myotis, and northern myotis, as well as several other hibernating bat species and is estimated to have resulted in the deaths of more than 5.7 million bats throughout North America. Since its initial discovery in North America in 2006/2007, white-nose syndrome has spread rapidly and now occurs throughout most of the northeastern United States (U.S.) and southeastern Canada. The discovery in 2016 of white-nose syndrome in the Pacific northwestern U.S. substantially extends its North American range. Population dynamic models predict a 99% extinction of little brown myotis in eastern Canadian provinces and the eastern U.S. by 2026 with equally devastating extinction rates for northern myotis. Fatality rates vary by bat species and are typically much greater for smaller bodied *Myotis* than big brown bats. WNS has not been detected in the NWT but is estimated at current expansion rates to reach the NWT from eastern North America in approximately 12 to 18 years.

If population declines occur in the NWT due to the arrival of WNS, adjoining provinces (e.g., Alberta and British Columbia) will most likely also have been infected with the fungus (*Pseudogymnoascus destructans*) that causes white-nose syndrome and would be experiencing the same population losses, limiting the amount of 'rescue' possible. White-nose syndrome has not yet affected long-eared or long-legged myotis in the wild; however, the recent confirmation of the fungus in the U.S. Pacific northwest (within the ranges of both long-eared and long-legged myotis) may heighten the risk of exposure. Recognizing the recent occurrence of WNS in the U.S. Pacific northwest, it is conceivable that WNS could spread to distant locations as far away as the NWT much sooner than 12-18 years. Additional threats include human impacts at hibernacula (activities that change hibernacula conditions including accessibility, temperature, humidity, etc.), exclusion and removal of maternity roosts (non-lethal exclusion or lethal extermination by building owners, or incidental removal as a result of development activities), timber harvest, predation by common house cats, mercury contamination, and climate change.

Positive Influences

Bat research and monitoring efforts have increased in the NWT over the past 5-10 years, allowing for an increased understanding of bat species in the NWT. Local parks, governments, Aboriginal organizations and renewable resources boards have been involved in creating public awareness about bats in the communities, and engaging community members in education events and campaigns. There is currently a Draft Cave Management Plan under review for the South Slave hibernacula, which will assist proper management of this important hibernation area. In addition, little brown and northern myotis have recently been federally emergency listed as 'endangered' under the *Species at Risk Act*, which provides some protection for individuals and habitat. Territorial biologists and university researchers continue to participate in working groups such as the Western Bat Working Group, Western Canada Bat Working Group, Northern Bat Working Group, Canadian Inter-agency WNS Committee, and Canada Wildlife Health Cooperative, which help facilitate communication and coordination of bat conservation and monitoring efforts across jurisdictions.

Technical Summary

Population trends	
Generation time (average age of parents in the population) (indicate years, months, days, etc.).	Big brown bat: 6.8-8.5 years Little brown myotis: 5.0-16.0 years Northern myotis: 6.8-8.5 years Long-eared myotis: 7.6-10.0 years Long-legged myotis: 7.3-9.5 years
Number of mature individuals in the NWT (or give a range of estimates).	Unknown; >3,700 little brown and northern myotis at known hibernacula, but population estimates for the five species in the NWT are otherwise unavailable. However, the NWT population of bats is certainly higher than the population seen just at known hibernacula.
Percent change in total number of mature individuals over the **last** 10 years or 3 generations, whichever is longer.	Unknown, but decline not expected.
Percent change in total number of mature individuals over the **next** 10 years or 3 generations, whichever is longer.	Unknown.
Percent change in total number of mature individuals over any 10 year or 3 generation period which includes **both the past and the future.**	Unknown.
If there is a decline in the number of mature individuals, is the decline likely to continue if nothing is done?	Unknown.
If there is a decline, are the causes of the decline	Unknown.

reversible?	
If there is a decline, are the causes of the decline clearly understood?	Unknown.
If there is a decline, have the causes of the decline been removed?	Unknown.
If there are fluctuations or declines, are they within, or outside of, natural cycles?	Unknown.
Are there 'extreme fluctuations' (>1 order of magnitude) in the number of mature individuals?	Unknown.
Distribution Trends	
Estimated extent of occurrence in the NWT (in km^2).	Big brown bat: 163,307 km^2 Little brown myotis: 320,122 km^2 Northern myotis: 135,568 km^2 Long-eared myotis: 32,238 km^2 Long-legged myotis: 14,578 km^2
Index of area of occupancy (IAO) in the NWT (in km^2; based on 2 × 2 grid).	Big brown bat: 71,576 km^2 Little brown myotis: 237,944 km^2 Northern myotis: 117,588 km^2 Long-eared myotis: 32,284 km^2 Long-legged myotis: 14,144 km^2
Number of extant locations[1] in the NWT.	Using white-nose syndrome (WNS) as the most serious plausible threat to bats in the NWT, there is one location for each species.

[1] Extant location – The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a species is

	In the absence of WNS however, the most serious plausible threat is the disturbance or destruction of hibernacula/maternity roosting areas. Using known hibernacula/maternity roosting areas as a minimum (many more hibernacula/maternity roosting areas are expected to be present throughout the NWT), the number of locations is at least: Big brown bat = 1-2 Little brown myotis = 5 Northern myotis = 2-4 Long-eared myotis = unknown Long-legged myotis = unknown
Is there a **continuing decline** in area, extent and/or quality of habitat?	Unknown, but not expected.
Is there a **continuing decline** in number of locations, number of populations, extent of occupancy and/or IAO?	Unknown.
Are there extreme fluctuations (>1 order of magnitude) in number of locations, extent of occupancy and/or IAO?	Unknown.
Is the total population severely fragmented (most individuals found within small and isolated populations)?	No.

affected by more than one threatening event, location should be defined by considering the most serious plausible threat.

Immigration from populations elsewhere	
Does the species exist elsewhere?	Yes.
Status of the outside population(s)?	Unknown but presumed stable in adjacent provinces and territories. As of September 2016, WNS has not yet arrived in adjoining provinces/territories. Little brown myotis and northern myotis severely declining in eastern North America.
Is immigration known or possible?	Yes; however, if population declines occur due to the arrival of WNS, adjoining provinces (e.g., Alberta and British Columbia) will most likely also have been infected with *Pseudogymnoascus destructans* (the fungus that causes WNS) and would be experiencing the same population losses, limiting the amount of 'rescue' possible.
Would immigrants be adapted to survive and reproduce in the NWT?	Yes.
Is there enough good habitat for immigrants in the NWT?	Yes; however, if WNS arrives in the NWT then hibernacula will likely be contaminated, rendering habitat unsuitable for immigrants.
Is the NWT population self-sustaining or does it depend on immigration for long-term survival?	Unknown.
Threats and limiting factors	
Briefly summarize negative influences and indicate the magnitude and imminence for each.	White-nose syndrome – Severe (not yet present in the NWT, but imminent), 12-18 years to reach the NWT from eastern North America at current rates of expansion. Human impacts at hibernacula – Minimal, current. Exclusion and removal of maternity roosts – Minimal, current.

	Habitat loss and degradation (timber harvest) – Minimal, current and increasing in the immediate future.
Positive influences	
Briefly summarize positive influences and indicate the magnitude and imminence for each.	Research and monitoring, public education events, and community engagement – Ongoing. Cave Management Plan – Pending. National emergency listing of little brown myotis and northern myotis as ‘endangered’ under the *Species at Risk Act* (offers some protection for individuals and habitat and proposes management measures through the posting of a federal recovery strategy). Participation of local biologists in cross-regional working groups that facilitate information sharing and coordination.

PREAMBLE

At least 7, possibly 8 species of bats are found in the Northwest Territories (NWT): big brown bat (*Eptesicus fuscus*), little brown myotis (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), long-eared myotis (*Myotis evotis*), long-legged myotis (*Myotis volans*), hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*), and likely eastern red bat (*Lasiurus borealis*). This report focuses on the first five species (*Eptesicus* and *Myotis*) because they are hibernating species that are vulnerable to white-nose syndrome (WNS) and therefore of conservation concern.

SPECIES OVERVIEW

Names and classification

Scientific Names:	*Eptesicus fuscus*, Palisot de Beauvois (1796) *Myotis lucifugus*, LeConte (1831) *Myotis septentrionalis*, Trouessart (1897) (classified as *Myotis keenii* prior to 1979) *Myotis evotis*, H. Allen (1864) *Myotis volans*, H. Allen (1866)
Common Names (English):	Big brown bat Little brown myotis, little brown bat Northern myotis, northern long-eared bat Long-eared myotis, western long-eared bat Long-legged myotis, hairy-winged bat
Common Names (French):	Sérotine brune Vespertilion brun Vespertilion nordique Vespertilion à longue oreilles Vespertilion à longue pattes

Common Names (Traditional; general):	Tsáret'áné (bat) (Chipewyan – Deninu Kue and Łutsel K'e) (South Slave Divisional Education Council [SSDEC] 2012, 2014) Gútłóolía dlų̨ą det'onı (bat) (South Slavey - Kátł'odeeche) (SSDEC 2009) Dléa det'ǫne (flying squirrel) (Shúhta/Shíhta Got'į̨ne or Mountain and K'áalo Got'į̨ne or Willow Lake dialects [Tulıt'a], Délı̨nę Got'ı̨ne, K'ásho Got'ı̨ne [Fort Good Hope and Colvılle Lake]) (Sahtú Renewable Resources Board [SRRB] and Species at Risk Secretariat 2013) Daatsadh natandıt'ee (flying mouse) (Gwichyah Gwich'in) (Gwich'in Language Centre and Gwich'in Social and Cultural Institute [GSCI] 2005) Daatsoo natındıt'ee (flying mouse) (Teetl'it Gwich'in) (Gwich'in Language Centre and GSCI 2005)

Class:	Mammalia
Order:	Chiroptera
Family:	Verpertilionidae (Vesper bats)
Life Form:	Vertebrate, mammal, bat

Systematic/taxonomic clarifications

Myotis septentrionalis was formerly considered a subspecies of *M. keenii* (van Zyll de Jong 1979). Much of the older literature using the name *M. keenii* pertains to *M. septentrionalis*. *M. septentrionalis* was first considered as a separate species by Jones *et al.* (1992) and was formally recognized as a species distinct from *M. keenii* in Wilson and Reeder (2005).

There is new genetic evidence suggesting that *M. keenii* and *M. evotis* are a single species that interbreeds (Lausen *et al.* 2016). This work is not yet published.

Description

All five bat species being discussed in this report are various shades of brown in colour, with males being slightly smaller than females. Their body size and fur colour make these five species distinguishable from the three other bat species in the NWT (eastern red, silver-haired, and hoary bat). The largest of the five species is the big brown bat, with the four *Myotis* species being smaller-bodied bats. It is difficult to distinguish between the *Myotis* species given their similarities in size and colour. General morphometric descriptions are listed by species below. A labeled anotomical drawing is included in *Appendix A* (Fig. 27, p. 119) for reference. Echolocation call characteristics have been described for all five species (Fenton and Barclay

1980; Warner and Czaplewski 1984; Faure *et al.* 1990; Kurta and Baker 1990; Caceres and Barclay 2000). Species identification by echolocation call however, is a complex process and will not be discussed in detail here.

Big brown bat

Figure 1. Big brown bat (*Eptesicus fuscus*) (photo credit: Jesika Reimer).

Average total length and forearm length are 116 millimeters (mm) and 47.5 mm, respectively (Nagorsen and Brigham 1993). Average mass is 14-21 grams (g) (Adams 2003). NWT captures (n = 100) report a mean (±SD) forearm length of 46 mm (±1.5) and a mean mass of 18 g (±2.5) (Reimer unpubl. photos 2013). The big brown bat can be distinguished from the *Myotis* species by its large size, and from species such as the eastern red, hoary, and silver-haired bats by its brown colour. For comparison, the eastern red bat has bright red hair, the hoary bat has distinct yellow hair around the neck and on the interfemoral wing membrane, and the silver-haired bat has dark, silver-tipped hair (Nagorsen and Brigham 1993).

Little brown myotis

Figure 2. Little brown myotis (*Myotis lucifugus*) (photo credit: Jesika Reimer).

Average total length and forearm length are 86 mm and 36.4 mm, respectively (Nagorsen and Brigham 1993). Average mass is 7-14 g (Adams 2003). NWT captures (n = 725) report a mean (±SD) forearm length of 38.9 mm (±1.6) and a mean mass of 8.8 g (±1.3) (Reimer unpubl. data 2013a). The little brown myotis has a short, blunt tragus (a small flap of cartilage in the external ear; average length = 7 mm) and ears that do not extend past its nose when pushed forward (average length = 13 mm; Adams 2003). Its calcar (cartilage frame for the tail membrane) does not have a keel (flap of skin extending beyond the calcar). The little brown myotis is distinguishable from the northern and long-eared myotis by its shorter ears and tragus, and from the long-legged myotis by both its lack of keel on the calcar and shorter body and forearm length.

Northern myotis

Figure 3. Northern myotis (*Myotis septentrionalis*) (photo credit: Laura Kaupas) with a radio transmitter attached to its back.

Average total length and forearm length are 87 mm and 36.1 mm, respectively (Nagorsen and Brigham 1993). Average mass is 6.5 g (5.0-10.0 g) (Nagorsen and Brigham 1993; Caceres and Barclay 2000). NWT captures (n = 89) report a mean (±SD) forearm length of 37.0 mm (±2.2) and a mean mass of 7.0 g (±0.8) (Reimer unpubl. data 2013a). The northern myotis has no keel on the calcar, a long, wispy tragus (average length = 10 mm), and ears that extend past the nose when pushed forward (average length = 17 mm) (Caceres and Barclay 2000; Adams 2003). It is distinguishable from the little brown and long-legged myotis by its long ears and thin, wispy tragus. The northern myotis is similar to the long-eared myotis, yet is distinguishable by its shorter ears (extend less than 5 mm past the nose when pushed forward), uniform fur colour (no distinct shoulder patch), and sparse fringe hairs on the outer edge of the tail membrane (Nagorsen and Brigham 1993).

Long-eared myotis

Figure 4. Long-eared myotis (*Myotis evotis*) (photo credit: Donald Solick).

Average total length and forearm length are 92 mm and 38.4 mm respectively. Average mass is 5.5 g (4.2-8.6 g) (Nagorsen and Brigham 1993). The long-eared myotis has no keel on the calcar, a long, slender tragus (average length = 10 mm), and the longest ears of all North American *Myotis*, which extend 5 mm or more past the nose when pushed forward (average length = 20 mm; Adams 2003). The long-eared myotis can be distinguished from the other *Myotis* species by these long ears and blackish brown shoulder patch colouring (Nagorsen and Brigham 1993). Their ears and other membranes are usually black (Barbour and Davis 1969). The single long-eared myotis captured in the NWT was similar in size and mass to populations farther south (Lausen 2006).

Long-legged myotis

Figure 5. Long-legged myotis (*Myotis volans*) (photo credit: Donald Solick).

Average total length and forearm length are 94 mm and 38.3 mm, respectively. Average mass is 7.2 g (5.5 – 10.0 g) (Nagorsen and Brigham 1993). This species is the largest *Myotis* species in the NWT with a prominent keel on the calcar, a short, blunt tragus (average length = 6 mm), and short ears that do not extend past the nose when pushed forward (average length = 12 mm; Adams 2003). The long-legged myotis can be distinguished from the other *Myotis* species by its keeled calcar and the light layer of fur on the underwing occurring from the elbow to the knee (Barbour and Davis 1969). NWT captures (n = 3) report a similar size and mass compared to populations farther south (Lausen 2006).

Distribution

Continental (Figs. 7, 9, 11, 13, 15, pgs. 33-43) and NWT distribution (Figs. 8, 10, 12, 14, and 16, pgs. 35-44) are presented in the pages that follow for each of the five bat species (big brown bat, little brown myotis, northern myotis, long-eared myotis, and long-legged myotis).

Existing continental range maps for bat species (International Union for the Conservation of Nature [IUCN] 2012; Environment and Natural Resources [ENR] 2014b) were modified for this report by J. Reimer and P. Lema (Alaska Natural Heritage Program [AKNHP]) using watershed and ecoregion boundaries in conjunction with additional point occurrence data obtained for Alberta (Fisheries and Wildlife Management Information System [FWMIS] 2015), British Columbia (British Columbia [BC] Ministry of Environment 2008), and the NWT (Wilson *et al.*

2014) to inform range extensions and delineation (Figs. 7, 9, 11, 13, 15, pgs. 33-43). Additional point occurrence data could not be obtained for the Yukon, but point data from Slough *et al.* (2014) were digitized for the purpose of building these continental range maps.

Range maps for each species in the NWT were developed using a variety of occurrence records including captures, photos, acoustic recordings, sightings, and museum specimens, in conjunction with watershed and ecoregion boundaries to inform suspected range delineations. Since *Myotis* species have similar physical characteristics and can have overlapping echolocation call characteristics, there is some uncertainty associated with photos, acoustic recordings, and sighting records compared to the more reliable capture and museum records. Records are marked as 'confirmed' or 'unconfirmed' to indicate the level of certainty as in Wilson *et al*. (2014) (Figs. 8, 10, 12, 14, and 16, p. 35-44). Observations of bats that could not be identified to species (e.g., acoustic recordings, photos, or sightings lacking diagnostic features) were not deemed as reliable evidence of a species' occurrence for the range maps. However, they have been compiled and are displayed at the end of this section (Fig. 17, p. 45). Given the limited search effort in the NWT (see *Search Effort*, p. 47), range maps will likely change as search effort increases and more captures are documented throughout the territory.

Extent of occurrence, area of occupancy, and index of area of occupancy (IAO) were also calculated for each species. Extent of occurrence is defined by the NWT Species at Risk Committee (SARC) (2015) as the area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a species. Area of occupancy is defined by SARC (2015) as the area within the extent of occurrence that is occupied by a species, excluding cases of vagrancy. Since survey effort is relatively sparse across the territory, the extent of occurrence and area of occupancy were both estimated using the current range polygon for each species rather than occurrence records. Extent of occurrence was calculated for each species by connecting the outer edges of the current range polygon and area of occupancy was calculated as the total area of the range polygon within the extent of occurrence. To avoid inconsistencies and bias in assessments caused by estimating area of occupancy at different scales, IAO was calculated for each species. The IAO was measured as the surface area of 2 km x 2 km grid cells that intersect the actual area occupied by the wildlife species (i.e., area of occupancy).

The number of extant locations for each species was also identified. SARC (2015) defines 'location' as a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a species is affected by more than one threatening event, location should be defined by considering the most serious plausible threat.

WNS constitutes the most serious plausible threat for all five species (see *Threats and limiting* *factors – emerging disease*, p. 73), with infection at hibernacula usually resulting in severe population declines or extirpation. At current rates of expansion from eastern North America, WNS could reach the NWT in approximately 12-18 years (Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2013). In the presence of WNS there could be considered to be one location in the NWT for each species (big brown bat, little brown myotis, northern myotis, long-eared myotis, and long-legged myotis) (COSEWIC 2013). In the absence of WNS however, the most serious plausible threat remains the disturbance or destruction of hibernacula/maternity roosting areas. Using known hibernacula/maternity roosting areas as a minimum (understanding that more hibernacula/maternity roosting areas are expected to be present in the NWT), the number of extant locations can be estimated as at least: big brown bat = 1-2, little brown myotis = 5, northern myotis = 2-4, long-eared myotis = unknown, and long-legged myotis = unknown (Lausen 2006; Lausen 2011; Reimer and Kaupas 2013; Reimer unpubl. data 2013a; Wilson *et al.* 2014; Cox pers. comm. 2015; ENR unpubl. data 2015; Kaupas 2015).

The NWT mainland is composed of seven level II ecological regions (ecoregions): Southern Arctic – Tundra Plains, Southern Arctic – Tundra Shield, Tundra Cordillera, Boreal Cordillera, Taiga Cordillera, Taiga Plains, and Taiga Shield (Fig. 6, p. 32; Ecosystem Classification Group 2007 [rev. 2009], 2008, 2010, and 2012). These ecoregions are defined by their climatic, physiographic, and vegetative characteristics and are as such, relevant to discussions on habitat and distribution. The southern boundary of the Southern Arctic (Tundra Plains and Shield) ecoregion approximates the tree line (Ecosystem Classification Group 2012). During summer, bats have been observed in three of these regions: Boreal Cordillera, Taiga Plains, and Taiga Shield, with all observations occurring below the treeline (described *in* Wilson *et al.* 2014). The known winter distribution is concentrated at hibernation sites in the South Slave region in the Taiga Plains (two known hibernacula: SSR-1 and SSR-2; Fig. 19, p. 48); however, additional hibernacula may exist elsewhere in the territory.

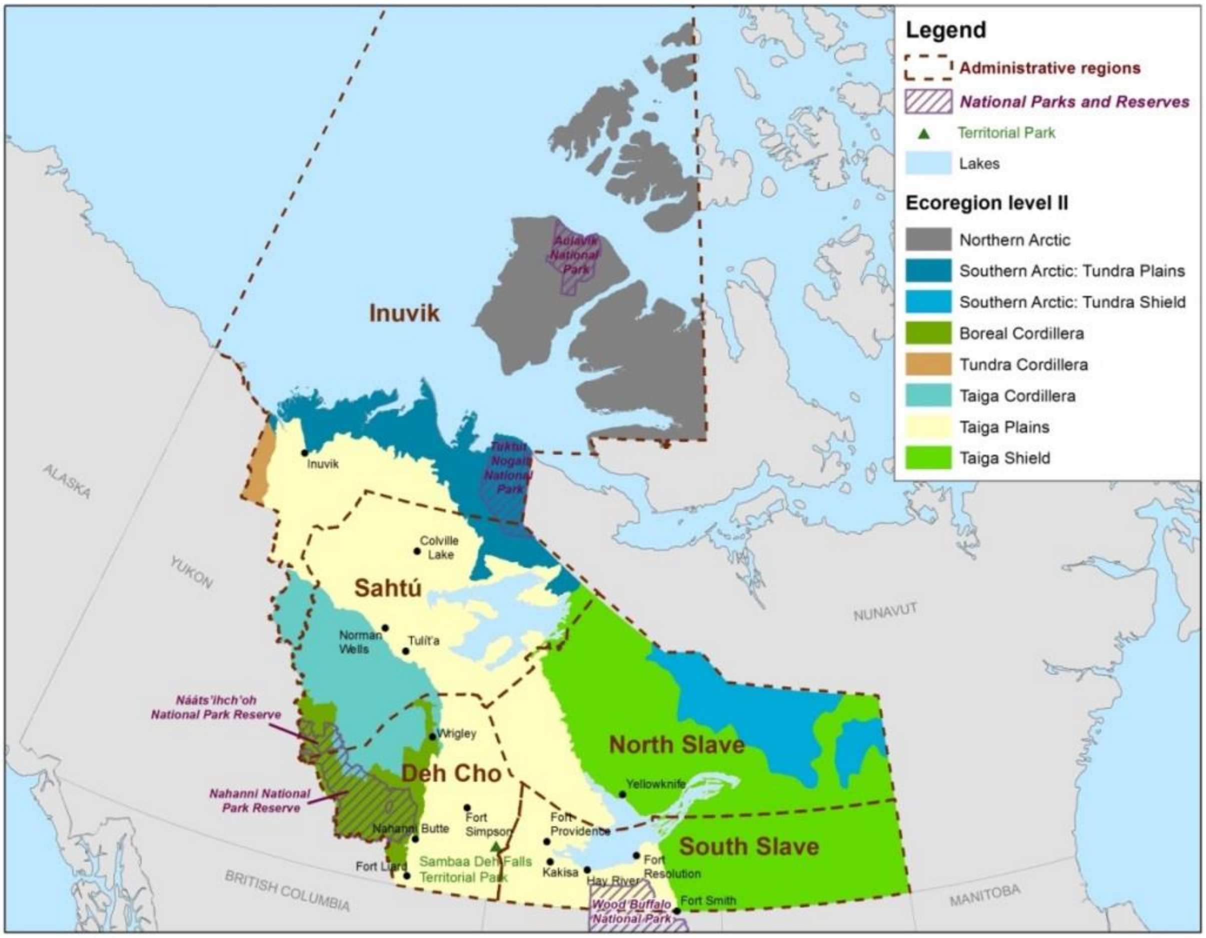

Figure 6. NWT ecoregions, administrative regions and place names mentioned throughout this report. Map was produced by J. Reimer (AKNHP) with data provided by Environment and Natural Resources (ENR). Ecoregion delineations are from Ecosystem Classification Group (2007 [rev. 2009], 2008, 2010, and 2012).

Big brown bat

The big brown bat is found across North America from Canada to the northern tip of South America, including Columbia and northern Venezuela (Fig. 7, p. 33; Miller *et al.* 2008). Its confirmed distribution in Canada includes all provinces and territories except Yukon and Nunavut. Distribution in the United States (U.S.) includes all continental states except Alaska[2] (NatureServe 2014).

[2] There is one record of big brown bat in Alaska; however, since its discovery in 1955 (Reeder 1965), no additional evidence to support the presence of big brown bat in Alaska has been found. It is therefore believed to be incidental and that the specimen was potentially brought in on a truck (Parker *et al*. 1997).

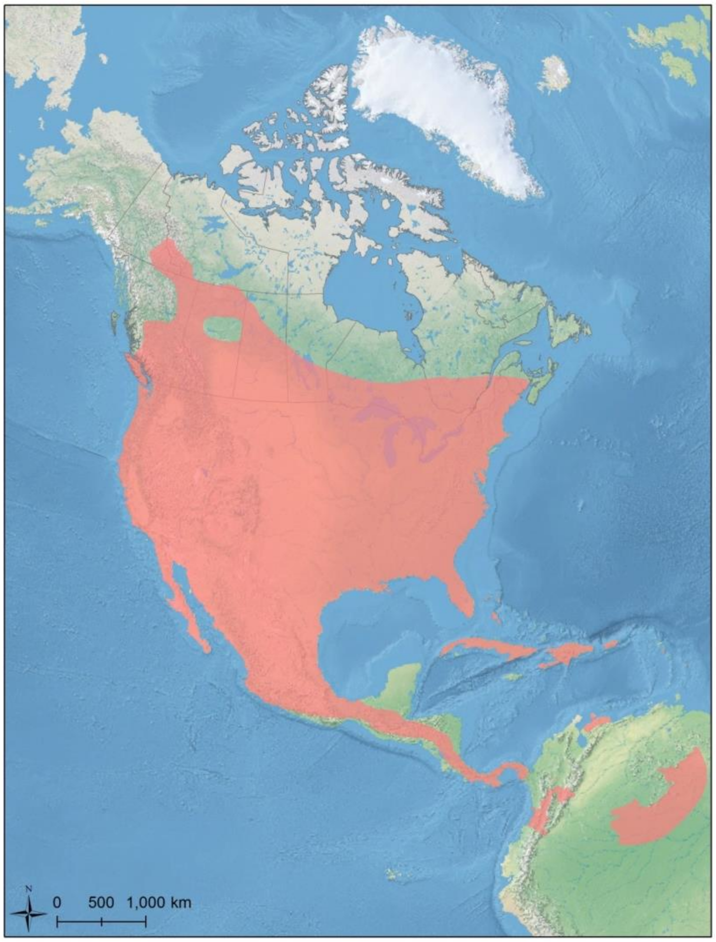

Figure 7. Continental range for the big brown bat (*Eptesicus fuscus*). Modified from International Union for the Conservation of Nature (IUCN) (2012) by J. Reimer and P. Lema (Alaska Natural Heritage Program [AKNHP]), C. Lausen (Wildlife Conservation Society), D. Player (Matrix Solutions), and J. Wilson and B. Fournier (ENR). The northwestern part of the range, which was extrapolated to include the Liard River watershed, should be considered the likely range of the species as big brown bat records from northern British Columbia, southwestern NWT, and the Yukon are all unconfirmed (acoustic recordings and sightings but no captures or specimens; Wilkinson *et al*. 1995, Vonhof *et al.* 1997; Government of Yukon 2011; Lausen *et al*. 2014). The gap in the range in northern Alberta reflects a large area with a lack of big brown bat records despite many surveys (Grindal *et al*. 2011; Player pers. comm. 2016).

In the NWT, the big brown bat has been observed in the Boreal Cordillera and Taiga Plains (Fig. 8, p. 35). More specific areas include the Fort Smith area, Wood Buffalo National Park, and Nahanni National Park Reserve (live-captures, sightings by a bat expert, and acoustic recordings; Wilson *et al.* 2014). Bats with low-frequency echolocation calls (very possibly big brown bats) have also been recorded at Lindberg Landing and Petitot River in the Liard River Valley (Wilson 2016), at Fort Resolution (Wilson 2014), and at Lady Evelyn Falls campground near Kakisa (ENR unpubl. data 2016a), suggesting big brown bats may also be found at these locations; however, further work is required to confirm species identification.

The big brown bat hibernates in the South Slave region (ENR unpubl. data 2015; Lausen 2006) and probably also in Wood Buffalo National Park, Alberta (Reimer *et al.* 2014). Neither reproductive females nor juveniles have been captured in the NWT; therefore, presence of breeding in the area is unknown. However, juveniles have been captured immediately south of the NWT in Wood Buffalo National Park, Alberta (Reimer *et al.* 2014; Klüg pers. comm. 2015); it is therefore possible that big brown bats are breeding in the South Slave region as well. Big brown bats have not been recorded at Sambaa Deh Territorial Park during multiple years of monitoring (Wilson 2016); however, low-frequency echolocation calls from Kakisa suggest big brown bats may occur there (ENR unpubl. data 2016b). Therefore it is not known whether the large area in the southern NWT (Fig. 8, p. 35) where the big brown bat has not been confirmed indicates disjunct western and eastern populations or a lack of search effort. There is also a large survey area around Fort McMurray, Alberta, directly south of Wood Buffalo National Park that reports a lack of big brown bat activity (Grindal *et al.* 2011; Player pers. comm. 2016). These activity voids may indicate patchiness of big brown bat habitat and/or presence across the landscape.

The population in the South Slave region is considered continuous with populations farther south in Alberta (e.g., Wood Buffalo National Park), and the population in Nahanni National Park Reserve may be continuous with nearby populations in British Columbia along the Liard watershed (Wilkinson *et al*. 1995; Vonhof *et al.* 1997).

Extent of occurrence for the big brown bat was calculated as 163,307 km^2. Area of occupancy was calculated as 68,007 km^2 and the IAO was calculated as 71,576 km^2.

Figure 8. Approximate distribution of the big brown bat (*Eptesicus fuscus*) and locations of species records in the NWT. Distribution was modified from IUCN (2012) by J. Reimer and P. Lema (AKNHP); species records are from Wilson *et al*. (2014). Bats with low-frequency echolocation calls (very possibly big brown bats) have also been recorded at Lindberg Landing and Petitot River in the Liard River Valley (Wilson 2016), at Fort Resolution (Wilson 2014), and at Lady Evelyn Falls campground near Kakisa (ENR unpubl. data 2016b); however, further work is required to confirm species identification.

Little brown myotis

The little brown myotis is the most widespread bat in North America and ranges east to west from Newfoundland and Labrador to Alaska at its northern limits, and from Florida to California at its southern limits (Fig. 9, p. 36; Arroyo-Cabrales and Álvarez-Castañeda 2008b). Distribution in Canada includes all provinces and territories except Nunavut[3]. Distribution in the U.S. includes all continental states except Arizona, Texas, and Louisiana (NatureServe 2014).

[3] Little brown myotis is suspected, but not confirmed in Nunavut (Wilson *et al*. 2014).

Figure 9. Continental range for the little brown myotis (*Myotis lucifugus*). The black dot represents a single confirmed record and question mark symbols represent uncertainty about the extent of northern range. Modified from ENR (2014b) by J. Reimer and P. Lema (AKNHP).

The little brown myotis is the most widespread and abundant bat species in the NWT and has been observed in the Boreal Cordillera, Taiga Plains, and Taiga Shield (Fig. 10, p. 38). More specific areas include the Nahanni area, the Mackenzie River Valley, the South Slave region, and north of Great Slave Lake. It is not known how far north the species occurs down the Mackenzie Valley. The most northern observation was a single specimen found in 2012 in Colville Lake, in the Sahtú region. It has been suggested that this specimen may be extralimital (occurring far outside known range), although there are unconfirmed reports of bats near Tulít'a, Norman Wells, and Wrigley, as well as in the Gwich'in region (Aklavik, Tsiigehtchic and Fort McPherson), which if confirmed may warrant a range extension (Wilson *et al*. 2014; Wilson pers. comm. 2015; Cooper pers. comm. 2016). There are two known hibernacula in the South Slave region: hibernacula SSR-1 and SSR-2 (Fig. 19, p. 48) (Lausen 2011; Wilson *et al.* 2014; Cox pers. comm. 2015). Little brown myotis have also been found overwintering in Walk-in Cave in Wood Buffalo National Park, just south of the NWT border (Reimer *et al.* 2014). Based on the limited information available, summer maternity colonies are expected to be smaller and more distributed across the region compared to hibernation sites (Wilson *et al.* 2014). Little brown myotis appears to reproduce across the South Slave and Dehcho regions. Three large maternity colonies (summer congregations of reproductive females and their young) have been identified at the Thebacha cabins near Fort Smith, Lady Evelyn Falls campground near Kakisa, and a private residence in Kakisa, and reproductive females have been captured in Nahanni National Park Reserve. Elsewhere in the Dehcho and South Slave regions there are reports of other groups of bats living in buildings that are possible but unconfirmed maternity colonies (Reimer 2013; Lausen *et al*. 2014; Wilson *et al.* 2014; ENR unpubl. data 2016b; Deneron pers. comm. 2016). The NWT population of little brown myotis is considered continuous with populations in adjacent provinces (Wilson *et al*. 2014).

Extent of occurrence for the little brown myotis (excluding the extralimital observation in Colville Lake) was calculated as 320,122 km^2. Area of occupancy was calculated as 233,865 km^2 and the IAO was calculated as 237,944 km^2.

Figure 10. Approximate distribution of the little brown myotis (*Myotis lucifugus*) and locations of species records in the NWT. Distribution was modified from ENR (2014b) by J. Reimer and P. Lema (AKNHP); species records are from Wilson *et al.* (2014).

Northern myotis

The northern myotis is present across Canada and the central and eastern U.S. (Fig. 11, p. 39; Arroyo-Cabrales and Álvarez-Castañeda 2008c). Distribution in Canada includes all provinces and territories with the exception of Nunavut (described *in* NatureServe 2014).

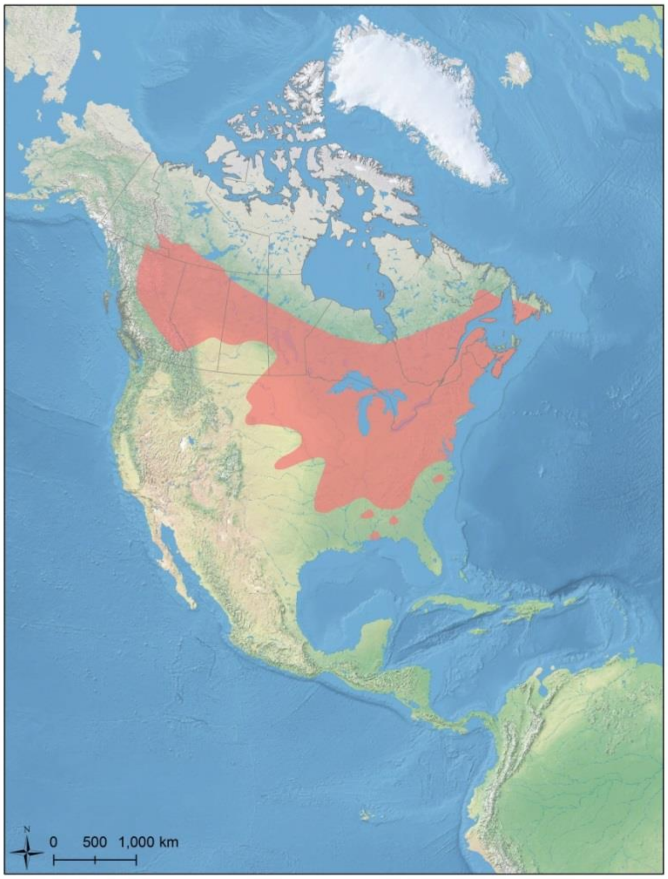

Figure 11. Continental range for the northern myotis (*Myotis septentrionalis*). Modified from ENR (2014b) by J. Reimer and P. Lema (AKNHP) and J. Wilson and B. Fournier (ENR).

In the NWT, northern myotis have been observed in the Boreal Cordillera and Taiga Plains (Fig. 12, p. 40). There are records from around Fort Smith and Wood Buffalo National Park, the Kakisa area, Nahanni National Park Reserve, and Fort Simpson (Reimer and Kaupas 2013; Lausen *et al.* 2014; Wilson *et al*. 2014). Reproductive females and active maternity colonies have been identified in the Fort Smith area (Reimer and Kaupas 2013; Kaupas 2015). Northern myotis have not been identified during winter cave surveys; however, individuals have been captured flying in and out of the SSR-1 hibernaculum (Fig. 19, p. 48) during spring and autumn (Reimer unpubl. data 2013a; Wilson *et al.* 2014); individuals were also captured flying out of Walk-in Cave in Wood Buffalo National Park, Alberta, in spring (Reimer *et al.* 2014). Since northern myotis roost in cracks and crevices (Griffin 1940; described *in* Caceres and Barclay 2000), it is possible they were hibernating in the cave but were not observed. Therefore, it is suspected that northern myotis may be overwintering in the SSR-1 and SSR-2 hibernacula. Given the ability of northern myotis to travel between summer and winter sites (see *Movements*, p. 51), and the close proximity of northern myotis directly south (Vonhof *et al*. 1997; Grindal *et* *al.* 2011; Reimer *et al.* 2014), it is likely that the NWT population is continuous with populations in adjacent provinces.

Extent of occurrence for the northern myotis was calculated as 135,568 km^2. Area of occupancy was calculated as 114,621 km^2 and the IAO was calculated as 117,588 km^2.

Figure 12. Approximate distribution of the northern myotis (*Myotis septentrionalis*) and locations of species records in the NWT. Distribution was modified from ENR (2014b) by J. Reimer and P. Lema (AKNHP) and J. Wilson and B. Fournier (ENR); species records are from Wilson *et al.*(2014).

Long-eared myotis

The long-eared myotis ranges across most of western North America. The northern-most extent ranges from the NWT to central British Columbia, western Alberta, and southern Saskatchewan in Canada (Fig. 13, below; Barclay 1991; Vonhof and Barclay 1996; Chruszcz and Barclay 2002; Lausen *et al*. 2014; Wilson *et al.* 2014). Distribution within the western U.S. includes the following states: Washington, Idaho, Montana, small portions of western North and South Dakota, Oregon, Wyoming, California (including Baja), Nevada, western Utah, northern Arizona, and northwestern New Mexico (Buseck and Keinath 2004; NatureServe 2014).

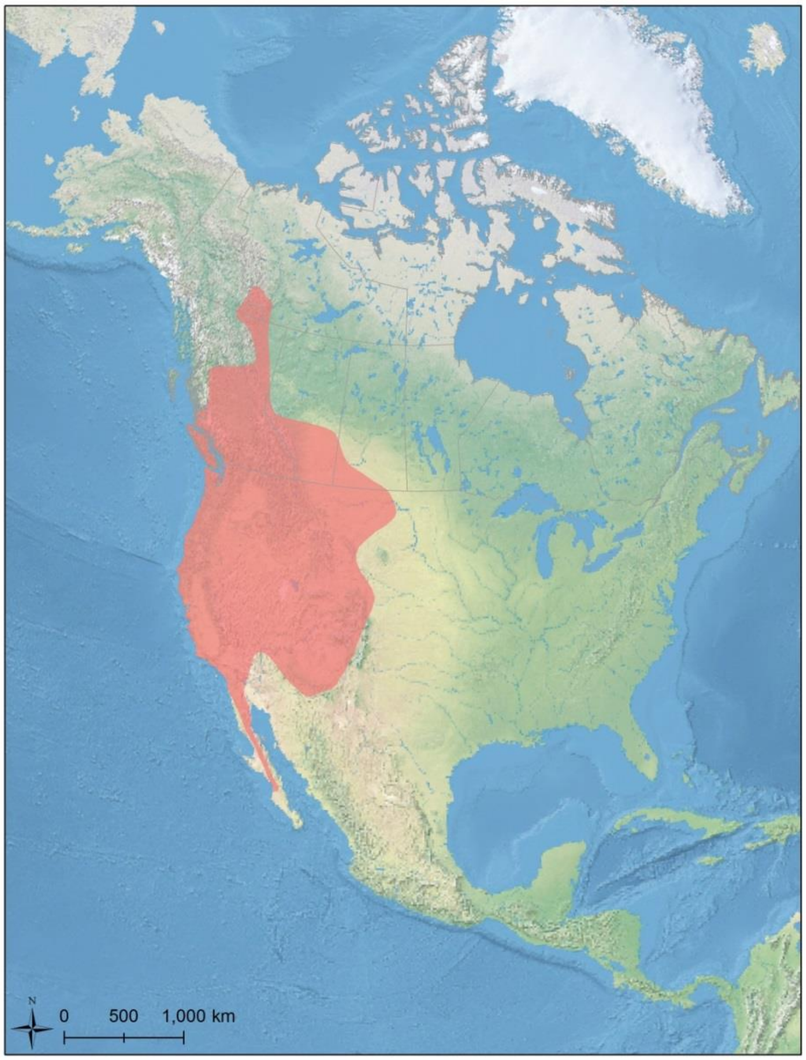

Figure 13. Continental range for the long-eared myotis (*Myotis evotis*). Modified from IUCN (2012) by J. Reimer and P. Lema (AKNHP) and J. Wilson and B. Fournier (ENR). The northwestern part of the range is estimated to include the Liard River watershed (based on records from Bradbury *et al*. (1997), Vonhof *et al*. (1997), Vonhof and Wilkinson (1999), and Lausen *et al.* (2014)), although there are no records of this species in the Yukon.

In the NWT, the long-eared myotis has been observed in the Boreal Cordillera; more specifically, the South Nahanni watershed. Observations are limited to one single capture and echolocation recordings at four locations, obtained during one survey in 2006 (Fig. 14, p. 42; Lausen *et al*. 2014; Wilson *et al.* 2014). Mist-netting surveys in the South Slave region have not yielded additional observations (Lausen 2011; Reimer 2013; Kaupas pers. comm. 2015); it is therefore likely that this population is smaller and more restricted in range than the little brown and northern myotis. Given the lack of occurrence data, it is unknown whether the NWT population is severely fragmented. However, given that long-eared myotis occurs farther south in the Liard watershed, British Columbia (Bradbury *et al.* 1997; Vonhof *et al.* 1997), it is likely that the NWT population is continuous with the adjacent population.

Extent of occurrence for the long-eared myotis was calculated as 32,238 km^2. Area of occupancy was calculated as 31,041 km^2 and the IAO was calculated as 32,284 km^2.

Figure 14. Approximate distribution of the long-eared myotis (*Myotis evotis*) and locations of species records in the NWT. Distribution was modified from IUCN (2012) by J. Reimer and P. Lema (AKNHP); species records are from Wilson *et al.* 2014).

Long-legged myotis

The long-legged myotis ranges across most of western North America from Alaska and Yukon south to Mexico (Fig. 15, p. 43; Arroyo-Cabrales and Álvarez-Castañeda 2008d). Distribution in Canada includes: Yukon, NWT, British Columbia, and Alberta (Vonhof and Barclay 1996; Lausen *et al*. 2014; Slough *et al.* 2014). Distribution in the U.S. includes: Alaska, Arizona, California, Colorado, Idaho, Montana, North Dakota, Nebraska, New Mexico, Nevada, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming (described *in* NatureServe 2014).

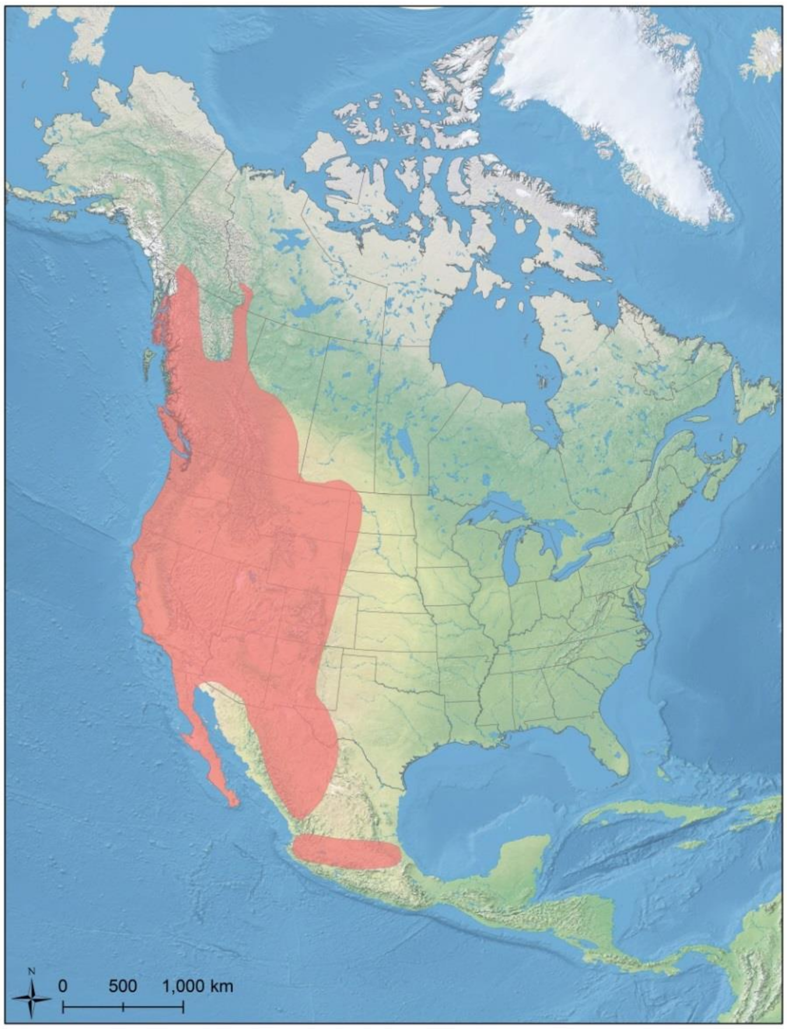

Figure 15. Continental range for the long-legged myotis (*Myotis volans*). Modified from IUCN (2012) by J. Reimer and P. Lema (AKNHP).

The long-legged myotis, similar to the long-eared myotis, has been observed in the Boreal Cordillera; more specifically, the South Nahanni watershed. Observations are limited to captures of three individuals at two adjacent locations at the southern end of Nahanni National Park Reserve, all obtained during one survey in 2006 (Fig. 16, p. 44; Lausen *et al*. 2014; Wilson *et al*. 2014). Mist-netting surveys in the South Slave region have not yielded additional observations (Lausen 2011; Reimer 2013; Kaupas pers. comm. 2015); therefore, similar to the long-eared myotis, it is likely that this population is smaller and more restricted in range than the little brown and northern myotis. Given the lack of occurrence data, it is unknown whether the NWT population is severely fragmented. However, given that long-legged myotis occurs farther south in the Liard watershed, British Columbia (Bradbury *et al.* 1997; Vonhof *et al.* 1997), it is likely that the NWT population is continuous with the adjacent population.

Extent of occurrence for the long-legged myotis was calculated as 14,578 km^2. Area of occupancy was calculated as 13,428 km^2 and the IAO was calculated as 14,144 km^2.

Figure 16. Approximate distribution of the long-legged myotis (*Myotis volans*) and locations of species records in the NWT. Distribution was modified from IUCN (2012) by J. Reimer and P. Lema (AKNHP); species records are

from Wilson *et al*. (2014).

Other bat observations

Additional observations of bats (species unknown) have been reported from other sites in the NWT (Fig. 17, p. 45; Wilson *et al*. 2014). These include bat sightings reported outside the currently known ranges of the eight NWT bat species; in particular, further north in the Mackenzie Valley (Tulít'a and Norman Wells areas, as well as the Gwich'in region) and further east in the Taiga Shield (Łutsel K'e and Hanbury River). Further surveys and confirmation of species in these areas could result in a range extension for one or more bat species.

Figure 17. Observations of unknown bat species (of the family Vespertilionidae) in the NWT. Map created by ENR using data compiled in Wilson *et al*. (2014) as well as additional information collected since 2013 (ENR unpubl. data 2016b; Cooper pers. comm. 2016).

Nahanni National Park Reserve currently has the greatest documented species diversity of bats in the territory (Lausen *et al.* 2014); however, thorough surveys outside of this region have been limited and future research may find similar diversity elsewhere (Wilson *et al*. 2014). Wilson *et al.* (2014) thought it likely that the lower Liard River Valley, between Nahanni Butte and British Columbia, would be found to have similarly high species diversity if surveyed. Bat detectors at Lindberg Landing and Petitot River in the Liard River Valley have recorded a high level of summer activity by multiple species of bats, including bats with low-frequency echolocation calls (likely big brown and/or silver-haired bats) as well as *Myotis* species (Wilson 2016). The Liard River system may act as a corridor for bats to move between northeastern British Columbia and southwestern NWT (Lausen *et al.* 2014).

Given the ability of flight, bats can travel long distances between summer and winter roosts (see *Movements*, p. 51). Dispersal in spring and promiscuous mating in large swarms during autumn promote genetic mixing and reduce genetic isolation (Burns *et al*. 2014). Genetic studies specific to the NWT are limited to a small sample of little brown myotis from the Fort Smith area that were included in a continental analysis (Wilder 2014). Wilder (2014) found that little brown myotis in the Fort Smith area and Wood Buffalo National Park directly south, were genetically similar to eastern populations including southern Alberta and Saskatchewan, suggesting no evidence of isolation of bats in the South Slave region and northern Alberta (Wilder pers. comm. 2015). Additional genetic analysis is needed to determine the potential isolation of bats in the Nahanni area given its mountainous terrain and the genetic uniqueness of bats directly west in the Yukon (Wilder 2014).

Search effort

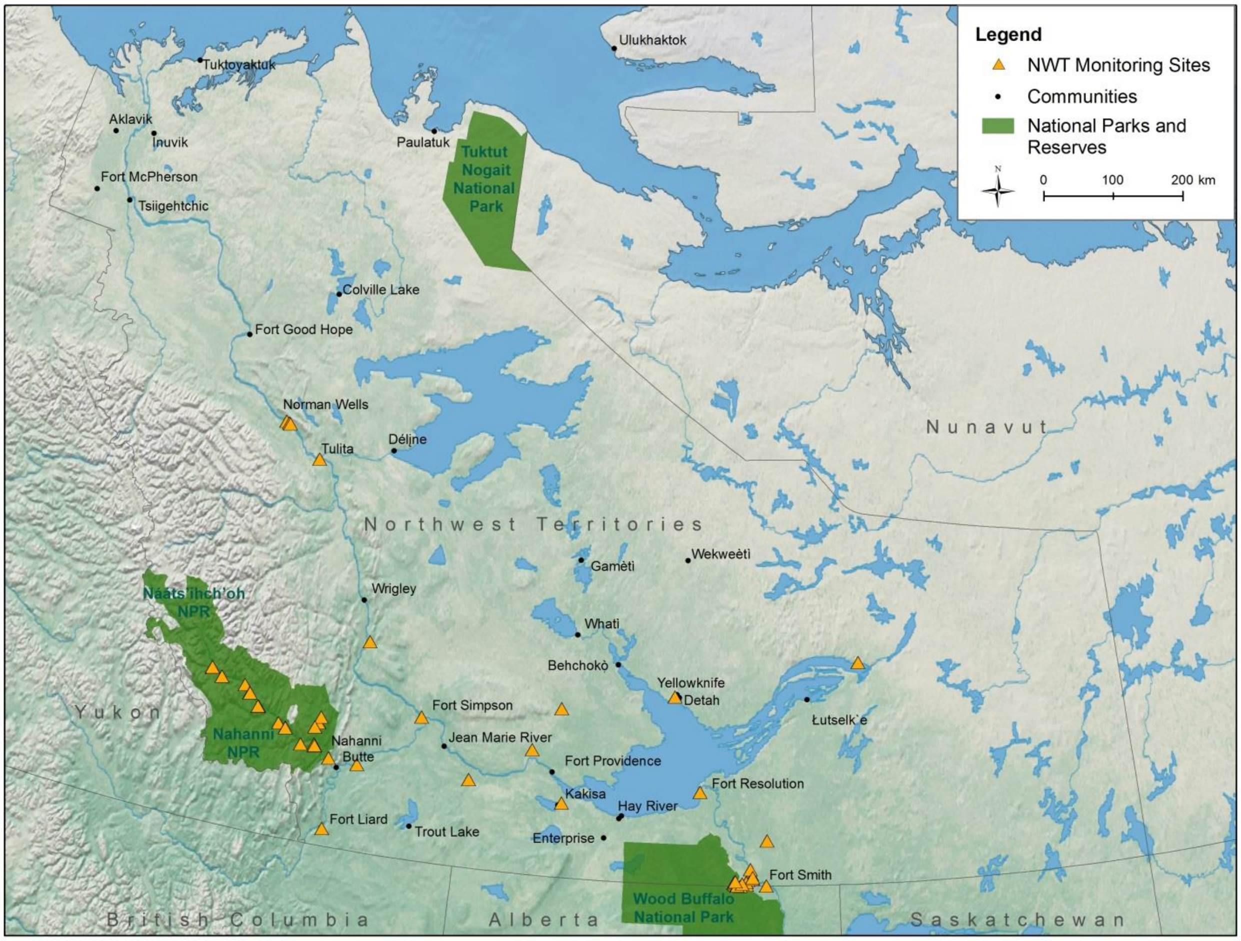

Figure 18. Locations of bat acoustic monitoring sites in the NWT for which recordings have been analyzed as of August 2016. Locations of the SSR-1 and SSR-2 hibernacula have been omitted due to location sensitivity. Level of monitoring effort is variable. Map created by ENR with information from Lausen (2011), Reimer (2013), Reimer unpubl. data (2013a), Lausen *et al*. (2014), Wilson (2014), Kaupas (2015), Kelly and Cox (2015), ENR unpubl. data (2016a), Reimer pers. comm. (2016), and Wilson (2016).

Observation types in the NWT for the five bat species under review include museum specimens, acoustic recordings, mist-net captures, opportunistic sightings, and photo documentation (Wilson *et al*. 2014). The greatest search effort has taken place in the South Slave region where multi-year studies of little brown and northern myotis have been ongoing since 2011 (Fig. 18, above; Reimer 2013; Kaupas 2015; Kelly and Cox 2015). These studies have focused on both targeted surveys at maternity colonies (mist-netting and acoustic monitoring; little brown and northern myotis) and general surveys at hibernacula and foraging sites such as beaver ponds (mist-netting and acoustic monitoring). Three main areas have been targeted in the region, including the

Thebacha cabins and campground west of Fort Smith, Lady Evelyn Falls campground near Kakisa, and the SSR-1 hibernaculum. Prior to these more recent ongoing studies, a 10-day survey was completed in 2010, which investigated the SSR-1 hibernaculum and described species presence in the surrounding area using acoustic recordings and mist-net captures at six sites (Lausen 2011). ENR has performed annual winter censuses and acoustic monitoring at the SSR-1 hibernaculum since 2010 (ENR unpubl. data 2015). Acoustic monitoring and winter censuses started at the SSR-2 hibernaculum after its discovery in 2014 (Kelly and Cox 2015) (Fig. 19, below).

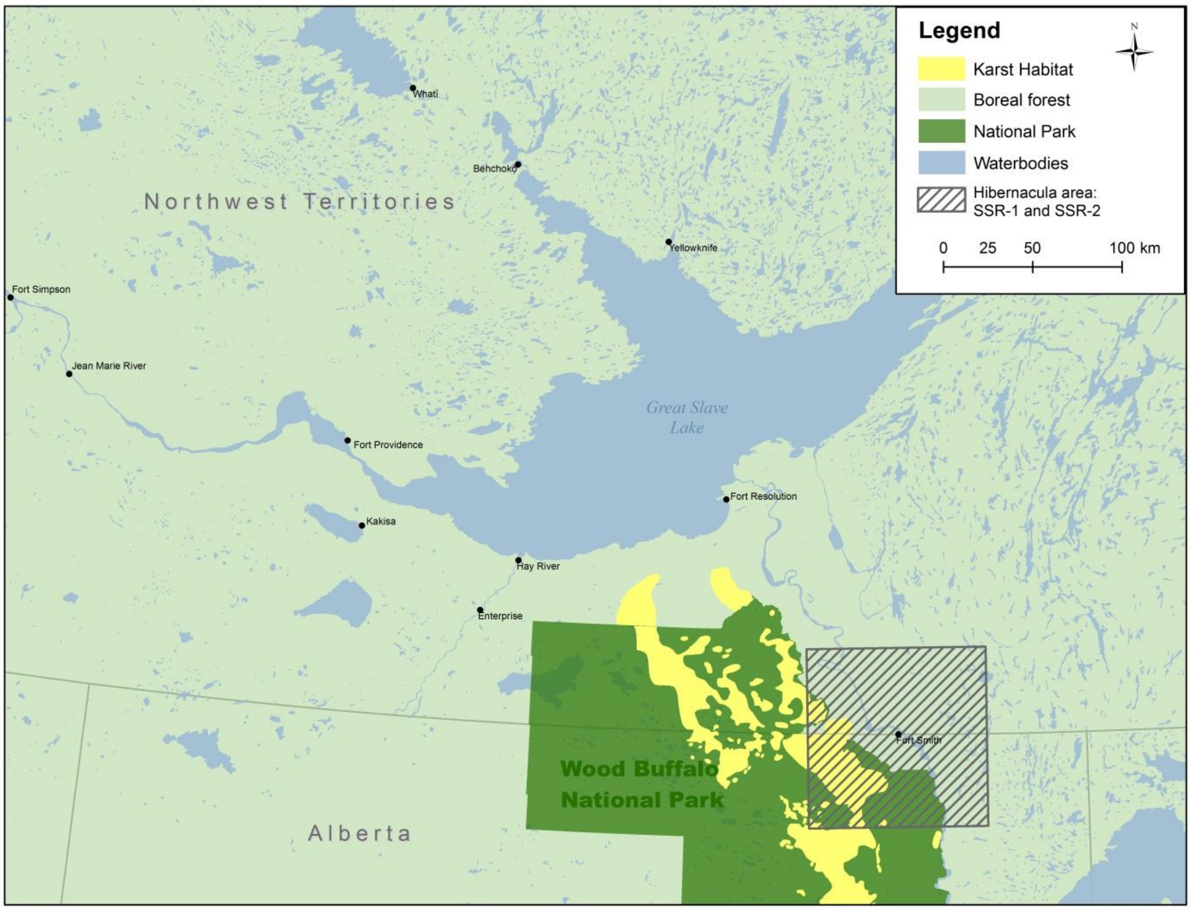

Figure 19. General location of bat hibernacula SSR-1 and SSR-2 in the South Slave region, NWT. Specific locations are deemed classified by ENR; contact A. Kelly, ENR

Many of the observations in Nahanni National Park Reserve and nearby area (Fort Simpson) were made during one intensive survey during July and August 2006 (Fig. 18, p. 47; Lausen *et al*. 2014). Survey effort included mist-netting for 15 nights at 15 sites, and acoustic monitoring for 23 nights at 39 sites.

Beginning in 2010, acoustic monitoring has been done at various other sites in the South Slave, North Slave, Dehcho, and Sahtú regions (Fig. 18, p. 47; ENR 2014c; Wilson 2014; Wilson *et al.* 2014; Wilson pers. comm. 2015; Wilson 2016). Monitoring was performed for varying lengths of time, with start dates ranging from 2010 to 2015. Locations sampled included Sambaa Deh Territorial Park, Willowlake River, the east side of the Horn Plateau, the Liard River Valley (Lindberg Landing and Petitot River), Yellowknife, Norman Wells, a site west of Tulít'a, Fort Resolution, and the East Arm of Great Slave Lake (Wilson 2016). Analysis has been completed for a subset of the collected data; further analysis of data may provide additional information for species range extensions. It is important to note that while some bat species have diagnostic calls, there is much overlap in call characteristics depending on the environment (e.g., habitat clutter) and echolocation passes are not always of sufficient quality to be identifiable to species. See Lausen *et al*. (2014) for descriptions of species-specific diagnostic call characteristics used for echolocation analysis in the NWT. Scattered bat records from the historical published literature were compiled by Wilson *et al*. (2014). Additional species records were obtained opportunistically and reported by staff of government and renewable resource boards as well as other members of the public.

The majority of the observation data collected in the NWT are positive (presence only) data. To date, survey effort and sample size are too limited to have enough confidence to declare negative (absence) data. However, acoustic monitoring in the Mackenzie Valley north of Fort Simpson and on Great Slave Lake east of Yellowknife has not yet recorded any bat calls. In addition, given the sparse sampling throughout the territory, the northern range limits of bat species have not been determined; however, there is no evidence to suggest that bats occur north of the treeline (Wilson *et al.* 2014).

BIOLOGY AND BEHAVIOUR

Physiology and adaptability

All five species use daily torpor[4] and seasonal hibernation to conserve energy during periods of low prey abundance (e.g., winter) and/or increased energetic expense (e.g., cooler temperatures). This behaviour allows them to survive extreme and/or unfavourable conditions (Audet and Fenton 1988; Thomas *et al*. 1990; Dzal and Brigham 2012).

During winter, access to hibernation sites with adequate temperature and humidity levels is required (see *Habitat requirements*, p. 62). If hibernacula temperatures drop below 0°C during hibernation, bats may increase their energetic use, drawing on fat stores to increase their

[4] Torpor is a state of lowered activity, metabolism, heart rate, respiration, and body temperature, and is used by individuals to conserve energy.

metabolism to arouse and look for a new hibernation site, or to account for cooler temperatures. Alternatively, bats may remain inactive and succumb to freezing (Davis and Reite 1967). Both responses result in decreased fitness of individuals. At Walk-in Cave in Wood Buffalo National Park, Alberta, winter temperatures (November-June) ranged from -1.1ºC to 0.8ºC in the portion of the cave where the majority of bats hibernated (Reimer *et al*. 2014). What effect these cold hibernating temperatures may have on energy expenditure is unknown.

During summer, bats require adequate food and water to support both summer reproduction and winter survival. Summer temperature tolerance varies by species. In more southerly locations, big brown bats do not leave their roosts when ambient temperature is below 10ºC (Brigham 1991). In the NWT, 5-6ºC has been suggested as a possible threshold for roost emergence (Rydell 1991; Talerico 2008; Reimer 2013). Long-legged myotis have been observed to be active at cooler temperatures than the little brown myotis (Schowalter 1980), which may suggest greater cold hardiness for this species. In Wood Buffalo National Park, Alberta, for all sampled *Myotis* species (big brown bat, little brown myotis, and northern myotis), night time activity was strongly positively correlated with temperature (Reimer *et al*. 2014).

At northern sites (NWT, Alberta and Yukon), the active period (emergence from hibernacula to return in the fall) has been documented to range between April/May to September/October (late April-late September [Sambaa Deh Territorial Park, NWT], mid- to late July until September/October [Yellowknife, NWT], until early October [Lindberg Landing and Petitot River, NWT] [Wilson 2016], mid-April to mid-October [Wood Buffalo National Park, Alberta] [Reimer *et al*. 2014], and mid-May to mid-September [Watson Lake, Yukon] [Talerico 2008]). With the exception of the Yellowknife, NWT site, these active season dates are comparable to the active seasons of populations further south (e.g., Norquay and Willis 2014; Meyer *et al*. 2016), despite cooler temperatures. However, Reimer (2013) found that reproductive activities of little brown myotis were delayed compared to southern sites, perhaps as the result of low prey availability at the time of emergence, increased torpor use by pregnant females, or delayed parturition (birth) to invest resources in fetal development or align lactation with the longer nights post-summer solstice (Reimer 2013).

The little brown myotis has a broad continental range and has proven to be adaptable in various habitats and environments. In the NWT, the little brown myotis has exhibited adaptability in its foraging behaviour and habitat use, selecting for spiders (an atypical prey type) during periods of cool weather (ambient temperature <10ºC; Kaupas and Barclay in prep.) and using the forest interior for foraging (Talerico 2008). Alterations in diet and foraging styles have also been observed in the Yukon (Talerico 2008; Lausen *et al.* in prep.) and Alaska (Whitaker and Lawhead 1992). These types of adaptations counter the inhibiting effect of lower temperatures on the availability of flying insects (Taylor 1963).

Bat foraging behaviour is nocturnal and this tends to remain true even in regions where summer nights are short (Speakman *et al*. 2000; Talerico 2008; Reimer 2013). This, combined with shorter summers overall and cool night time temperatures, may limit foraging opportunities and therefore resources available for growth, reproduction and accumulation of winter fat reserves, perhaps creating an effective northern limit to the distribution of bats.

Movements

All five bat species undergo annual dispersal events including inter- and intra-seasonal movements using flight. During each spring and autumn, individuals migrate between winter hibernacula and summer roosts. Little brown myotis have been observed travelling the largest distances; up to 650 kilometers (km) between summer and winter roosts (range: 10-650 km; Griffin 1945; Gifford and Griffin 1960; Fenton 1969; Norquay *et al.* 2013). Big brown bats typically travel shorter distances (24-87 km; Neubaum *et al.* 2006), as do northern myotis (up to 89 km; Griffin 1940). Movement patterns of long-eared and long-legged myotis between summer and winter sites are poorly studied throughout their range.

During summer, individuals may switch day roosts depending on environmental and reproductive conditions, and perform small nightly movements between day roosts and foraging sites (Vonhof and Barclay 1996; Cryan *et al.* 2001; Waldien and Hayes 2001; Lausen and Barclay 2002; Baker and Lacki 2006; Garroway and Broders 2008). Males and non-reproductive females are generally dispersed across the landscape and perform nocturnal movements between day roosts more frequently than reproductive females. Radiotelemetry studies in the north have recorded movement distances between day roosts and evening foraging sites at greater than 5 km for little brown myotis (Yukon, Randall *et al.* 2014) and approximately 2.2 km for northern myotis in the NWT (Kaupas pers. comm. 2015).

During mid-winter, the big brown bat has occasionally been observed moving between hibernacula (Beer 1955; Klüg pers. comm. 2015); however, distances have not been quantified.

Banding efforts for little brown myotis have been ongoing since 2011 in the South Slave region, mainly focusing on maternity colonies (Reimer 2013; Reimer and Kaupas 2013; Kaupas 2015). Banded little brown myotis have been observed in the SSR-1 hibernaculum, including two males that had been banded during spring at a beaver pond 2 km southeast of there (Cox pers. comm. 2015).

Life cycle and reproduction

The reproductive strategy of all five species is sexual reproduction with internal fertilization and live birth. Mating is indiscriminate and promiscuous and occurs primarily in swarms at hibernacula during autumn, prior to hibernation (Thomas *et al.* 1979). Females store sperm over winter and fertilize a single egg during spring ovulation when they leave hibernation (Fenton and

Barclay 1980; Warner and Czaplewski 1984; Caceres and Barclay 2000). Females produce a single offspring (called a pup). For big brown bats in western North America and for little brown myotis, twinning can occur but it is rare (Nagorsen and Brigham 1993). Individuals become sexually mature their first or second year (2-20 months for Vespertilionidae species; Barclay and Harder 2003). Females may be reproductively successful as yearlings if they are born early in the season and achieve adequate body condition for reproduction (Frick *et al.* 2010b), allowing multiple generations to overlap. Females may reproduce up to once per year; however, reproductive success is heavily influenced by regional weather patterns and females may forego reproduction in a year of poor resource abundance (Grindal *et al.* 1992; Frick *et al.* 2010b). Males may not become sexually mature until their second autumn swarming (Thomas *et al.* 1979).

All five species exhibit similar life cycle stages that include pre-fledged pup, pre-weaned fledgling[5], weaned fledgling, and reproductive adult. The duration of each reproductive phase (gestation, fledgling, and lactation) is determined by the extent of daily torpor use during pregnancy (increased torpor results in slower fetal development and longer pregnancy, as well as delayed and lower milk production in lactating females). The extent of daily torpor use is related to roost temperature, forage availability, and other environmental factors such as precipitation (Audet and Fenton 1988; Lausen and Barclay 2006a; Wojciechowski *et al.* 2007; Dzal and Brigham 2012; Kaupas 2015). Duration of gestation averages 69.4 days (SE = 34) for the Vespertilionidae family of bats (354 species including the five considered in this report). At birth, Vespertilionidae bats average 23.0% ± 8.0% of adult female mass (range 11.1-35%) and at first flight they average 75.0 ± 21.0% of adult female mass (Barclay and Harder 2003). Pups feed exclusively on milk until they fledge (Kurta *et al.* 1989), and weaning occurs on average 40.9 days (SE = 36) after birth (Barclay and Harder 2003). In big brown bats, gestation lasts for approximately 60 days (Kurta *et al*. 1990). Mass at birth for both big brown bats and little brown myotis is approximately 20-30% of adult female weight (Burnett and Kunz 1982). Lactation in big brown bats and little brown myotis lasts for approximately 34 and 26 days, respectively (Kurta *et al*. 1990). Similar life history information is unavailable for northern, long-eared, and long-legged myotis.

Energetic expenses for females increase throughout the reproductive cycle, with the greatest demands associated with lactation. With higher energetic demands, foraging duration and prey consumption increases (Belwood and Fenton 1976; Kurta *et al.* 1989; Brigham 1991; Reimer 2013). During hibernation, individuals rely on fat stores accumulated during summer and autumn to meet energetic expenses (Thomas *et al.* 1990).

Globally, the average lifespan for bat species in the family Vespertilionidae (composed of 354 species) is approximately 15 years (Barclay and Harder 2003). The following species-specific

[5] A fledgling is a juvenile bat that can fly.

maximum lifespans have been estimated based on banding recoveries: big brown bat – 9-19 years (Beer 1955; Cockrum 1956; Hitchcock 1965); little brown myotis – approx. 34 years (Davis and Hitchcock 1965; Keen and Hitchcock 1980); northern myotis – 19 years (Kurta 1995 *in* Wilkinson and South 2002); long-eared myotis – 16-22 years (Navo *et al.* 2002; Tuttle and Stevenson 1982); and long-legged myotis – at least 21 years (Tuttle and Stevenson 1982). Studies suggest a mean life expectancy of 5.65 years for the big brown bat (O'Shea *et al.* 2011), 6-7 years for little brown myotis (Keen and Hitchcock 1980), 2.2 years for long-eared myotis, and 2.1 years for long-legged myotis (Tuttle and Stevenson 1982). Mean life expectancy is not reported in the literature for northern myotis.

NWT reproduction

All five species are colonial breeders (see *Habitat Requirements*, p. 62). The proportion of adult females in reproductive condition at little brown myotis colonies in the South Slave region have been reported as 49-79% (two maternity colonies monitored for three years, 526 adult females assessed; Reimer 2013; Reimer and Kaupas 2013) and 79-81% (Thebacha maternity colony monitored for two years; Kaupas and Barclay 2015). Reimer (2013) found, over a two year period, that reproductive success varied by individual and by year. The majority (65%) of recaptured females (21 of 35) reproduced both years, while 26% reproduced only one of the two years (8 of 35) and 6% were not reproductive in either year (2 of 35). One juvenile was also recaptured and shown to be reproductive as a yearling. This is lower than those observed in more southerly locations (e.g., New Hampshire – 87-99%, Frick *et al.* 2010a; eastern U.S. - >96%, Cagle and Cockram 1943, Humphrey and Cope 1976) but higher than proportions observed in the Yukon (33-74%; Talerico 2008) and suggests that at least a portion of the population is healthy enough to reproduce annually (described *in* Reimer 2013). In general, reproduction in little brown myotis has been shown to decline with increasing latitude (Barclay *et al.* 2004). Sixty-eight percent of banded female recaptures in the South Slave region were reproductive for two consecutive years, suggesting that over half of the sampled population had a high enough body condition to support both reproduction and preparation for hibernation in consecutive years (Reimer 2013).

Reproductive proportions for northern myotis captured during 2014 and 2015 at maternity colonies were 80% (n = 5) and 66% (n = 18), respectively (Kaupas 2015; Kaupas and Barclay 2015), which is somewhat lower than observations at maternity sites farther south (e.g., 80%, West Virginia; Francl *et al.* 2012 and 97%, Illinois; Feldhamer *et al.* 2001).

Data do not exist to calculate reproduction proportions for the big brown bat, long-eared or long-legged myotis in the NWT; however, the following proportions have been observed in other locations throughout their ranges: big brown bat – generally exceeding 90% (Kurta and Baker 1990); long-eared myotis – 60-70% (Rocky Mountains, Alberta; Chruszcz and Barclay 2002;

Holloway 1998; Solick and Barclay 2006). Very little information exists for the long-legged bat and a reproductive rate for this species was not found in the literature.

NWT population structure

In the NWT, only two bat species have been captured in sufficient numbers to assess the percent of males and females in the population: little brown and northern myotis. Captures of these species are both female-biased at maternity colonies and male-biased at hibernacula and foraging sites, which is similar to what is observed elsewhere in their range (Agosta *et al.* 2005). Juvenile captures, which provide a better measure of sex ratio[6], in the NWT between 2011-2013 indicate a slight female bias for little brown myotis (53%; 84 of 158 individuals were female) and a male bias in captures for northern myotis (69%; 11 of 16 individuals were male; Reimer unpubl. data 2013a). These distributions are similar to a juvenile sex ratio of 1:1 for little brown myotis and northern myotis at more southerly locations (Central Appalachians; Agosta *et al.* 2005).

In other locations, capture studies suggest a male bias in adult populations of the big brown bat (68-79%; Agosta *et al.* 2005; Beer 1955), long-eared myotis (75%; Schowalter 1980), and long-legged myotis (53-76%; Barclay 1991; Johnson *et al*. 2007); however, this bias may be unique to the specific habitat type or location.

In the South Slave region, populations of little brown and northern myotis are composed of primarily middle-aged individuals (Table 1, below). This age structure is consistent across capture sites and species, as well as with observations for big brown bats, and little brown and northern myotis at more southerly locations (Agosta *et al.* 2005). Sample sizes for the big brown bat, long-eared and long-legged myotis in the NWT were too small to calculate age structure.

[6] Capture rates may be affected by the site, habitat, age, sex, and/or reproductive status of the bats, therefore capture rates are a potentially biased measure of the overall sex ratio in the population. The capture rate for male juvenile versus female juvenile bats should be more representative of the population sex ratio.

Table 1. Age class structure of little brown and northern myotis in the South Slave region of the NWT, measured over three years (2011-2013; Reimer unpubl. data 2013a). Age classes are determined by tooth wear; see Holroyd 1993 for details).

	Little brown myotis			Northern myotis		
Age class	**Maternity colony**	**Hibernacula**	**Forage site**	**Maternity colony**	**Hibernacula**	**Forage site**
Juvenile	135	0	23	7	0	9
Young (tooth wear 1-2)	17	1	3	1	0	1
Mid-age (tooth wear 3-5)	437	71	64	11	8	53
Old (tooth wear 6-7)	21	8	5	0	2	9
Total	*610*	*80*	*95*	*19*	*10*	*72*

Interactions

Interactions with prey

All five bat species are insectivorous and rely on adequate insect presence and abundance to support summer reproduction and winter survival (Speakman and Rowland 1999; Barclay *et al.* 2004).

Insectivorous bats employ two foraging strategies: 1) aerial hawking, whereby bats capture flying insects in the air and 2) gleaning, whereby bats catch insects off foliage or other surfaces. Big brown bats are primarily aerial hawkers. Little brown, northern, and long-eared myotis have flexible foraging behaviour and can use both methods, although northern and long-eared myotis are more specialized for gleaning than little brown myotis. Less is known about the foraging behaviour of long-legged myotis but it appears to be an aerial hawking species (Norberg and Rayner 1987; Fauré *et al.* 1993; Fauré and Barclay 1994; Ratcliffe and Dawson 2003; Ratcliffe *et al*. 2006). Using both aerial hawking and gleaning increases a bat's ability to diversify its diet and capitalize on available prey items throughout the season. Primary prey types for each species are described below.

Big brown bats feed on large-bodied insects, including beetles, moths, and caddisflies (Whitaker *et al*. 1977; Brigham and Saunders 1990; Hamilton and Barclay 1998). Long-legged myotis feed primarily on moths and beetles (Johnson *et al*. 2007), while northern myotis feed primarily on moths, beetles, caddisflies, true flies, and non-flying prey items such as spiders and moth larvae (Brack and Whitaker 2001). The little brown myotis feeds on a wide range of insect types, typically 4-9 mm in size (Buchler 1976; Fenton and Barclay 1980) and has been reported to consume spiders at the northern limits of its range (NWT, Kaupas and Barclay 2014; Alaska, Whitaker and Lawhead 1992; Yukon, Talerico 2008). The long-eared myotis typically feeds on beetles, moths, and other insects (Naughton 2012).

Food availability determines the timing of parturition, survivability of young, and ultimately, reproductive success (Arlettaz *et al.* 2001; Frick *et al*. 2010a). Species with a diverse foraging strategy and diet (e.g., little brown myotis) may be able to respond to environmental and anthropogenic changes better than those with less diverse foraging capabilities.

Interactions with predators

Natural predators of bats include owls, raptors, small carnivores, rodents, and snakes (Rysgaard 1942; Fenton and Barclay 1980; Blejwas and Kohan pers. comm. 2014). Common house cats also prey on bats roosting in buildings (Rysgaard 1942; O'Shea *et al*. 2011; Ancillotto *et al*. 2013). Numerous cat-related bat fatalities have been reported in the NWT; in some cases samples have been submitted to ENR in Fort Smith (Kelly pers. comm. 2014), but these incidences are not tracked formally and cannot be quantified. Mortality due to cats also occurs in the Yukon (Jung pers. comm. *in* Environment Canada 2015).

Parasites and disease

Bats host numerous external and internal parasites (Rysgaard 1942; Warner and Czaplewski 1984), including various species of the bat flea (genus *Myodopsylla*), the wing mite (genus *Spinturnix*), the bat bug (genus *Cimex*), and the soft tick (*Carios kelleyi*) (Dick *et al*. 2003; Lausen 2005; Pearce and O'Shea 2007; Czenze and Broders 2011). Ectoparasites have frequently been reported for both the little brown myotis and northern myotis in the NWT (between 2014-2016, parasites were present on 19-77% of sampled little brown myotis and 56-75% of northern myotis, although sample size was small; Reimer pers. comm. 2016) (Reimer unpubl. data 2013a; Reimer and Kaupas 2013); however, these parasites have not been identified to species and the impact these parasites have on the health of individuals has not been studied.

Rabies, caused by a virus (family Rhabdoviridae, genus *Lyssavirus*) and transmitted most often through saliva, has been reported in 30 of the 39 bat species that live in North America, north of Mexico (Constatine 1979). It persists at low levels in various populations (Nadine-Davis *et al.* 2001). The impact rabies has on bats is not clear; recorded die-offs may not be entirely attributable to rabies and there is some evidence of immunity in bats (i.e., 2% of little brown myotis had antibodies to the virus, but no lesions in the brain). This apparent immunity is difficult to confirm however, given incubation periods of sometimes over one year and the fact that apparently immune bats may simply not yet have been clinically affected (Messenger *et al.* 2003). Although Girard *et al.* (1965) noted that a proportion of bats appear to be rabid at any one time (<4% sample of apparently healthy big brown bats and <1% of little brown myotis), to date, no bats have tested positive for rabies in the NWT (8 little brown myotis and one northern myotis have been tested throughout the NWT; Elkin pers. comm. 2015; Kaupas pers. comm. 2016).

WNS is considered the most devastating disease for many cave-hibernating bat species in North America (Frick *et al.* 2010b) and is discussed in *Threats and limiting factors – Emerging disease*, p. 73).

Within species interactions

As discussed in *Life cycle and reproduction* (p. 51) and *Habitat requirements* (p. 62), all five species form maternity colonies of varying sizes and overwinter in hibernacula. These congregations allow for protection from predators (dilution effect; Fenton *et al.* 1994), reduce individual energetic expense due to increased collective body heat (Kunz and Lumsden 2003), and facilitate information transfer, gene flow, and social interaction (Jung *et al.* 2014).

Contact among individuals at maternity colonies and hibernacula, as well as autumn swarming behaviour, may facilitate the transmission of disease among bats. Disease transmission through bat-to-bat contact (at roost/hibernation sites or during swarming) (Lorch *et al*. 2011; Langwig *et al*. 2012; Fenton pers. comm. *in* COSEWIC 2013) and substrate contact (Lindner *et al*. 2011; Puechmaille *et al.* 2011; Chaturvedi *et al*. 2012; Kilpatrick 2013) have both been documented.

In this context, bat species that exhibit clustering behaviour in hibernacula to conserve body heat (e.g., little brown myotis), may be at higher risk for bat-to-bat disease transmission than species that roost alone (Lorch *et al.* 2011; Langwig *et al.* 2012). Substrate contact cannot be discounted as an important pathway to disease transmission however; for example, the tri-coloured bat has suffered high mortality rates from WNS despite individual hibernation behaviour (COSEWIC 2013).

Multi-species interactions

All five species are known to share multi-species winter hibernacula in more southerly locations (Rysgaard 1942; Schowalter 1980) and in the NWT, this behaviour has been observed for big brown bats, little brown myotis, and potentially northern myotis at the SSR-1 hibernaculum (Cox pers. comm. 2015). No multi-species shared maternity roosts have been located in the NWT (Wilson *et al*. 2014). As discussed above (*Interactions – within species interactions*, p. 57), the use of hibernacula may facilitate disease transmission through bat-to-bat and substrate contact. At multi-species hibernacula, disease transmission between species is possible.

Territorial behaviours such as aggressiveness or protectiveness have not been documented in these bat species within their known ranges (e.g., Fenton and Barclay 1980).

Interactions with humans

Bats are not harvested in the NWT; however, it is common across North America for many home/cabin owners to dislike bats roosting in their buildings and desire to remove them. This may result in the non-lethal exclusion of bats from their roosts and/or the lethal extermination of breeding colonies (Fenton and Barclay 1980). While the prevalence of this behaviour in the NWT is currently undocumented, extermination of individual bats is known to occur (Allaire pers. comm. 2016; Kelly pers. comm. 2016). Public education efforts are working to reduce the number of these incidences (Kelly pers. comm. 2016). Big brown bats, little brown myotis, northern myotis, long-eared myotis, and long-legged myotis are all insectivorous species and they're important predators of insects in the NWT. See *Positive influences* (p. 82) for more information on public education efforts and the construction of artificial maternity roosts.

STATE AND TRENDS

Population

Abundance

The global population for little brown myotis was estimated at 6.5 million in 2006 (Frick *et al.* 2010b); however, since then, over one million little brown myotis have been killed by WNS (see *Threats and limiting factors*, p. 73). There is no global population estimate for the northern myotis; however, COSEWIC (2013) estimated the pre-WNS population of northern myotis in Canada was likely over one million bats, and a rough estimate for only a portion of the midwest U.S. was over four million bats (Meinke pers. comm. 2015 *in* United States Fish and Wildlife Service [USFWS] 2015). Global population estimates are not available for the big brown bat, northern myotis, long-eared myotis, and long-legged myotis; however, NatureServe (2014) suggests that each population is likely greater than 100,000. The percent of global range for each species in Canada has been roughly estimated as: big brown bat, 17%; little brown myotis, 50%; northern myotis, 40%; long-eared myotis, 28%; and long-legged myotis, 23% (COSEWIC 2013). These percentages may give some indication of the proportion of each population that resides in Canada; however, comparative densities across the range are unknown.

Population size estimates are not available for any bat species in the NWT, but some general conclusions may be drawn about their relative abundance. The available data suggest that little brown myotis is the most common bat in much of Canada (Fenton and Barclay 1980; COSEWIC 2013), including the NWT (for example, 969 capture and specimen records were compiled by Wilson *et al*. 2014). Northern myotis is less common than little brown myotis in Canada and has a more restricted distribution (COSEWIC 2013), but is relatively common in the NWT (for example, 109 confirmed capture and specimen records were compiled by Wilson *et al*. 2014).

There is not enough information to determine relative abundance of big brown bat, long-eared myotis and long-legged myotis in the NWT, but their distribution appears to be more restricted; therefore, they are probably less abundant. The underrepresentation of the big brown bat, long-eared myotis, and long-legged myotis in NWT capture records is consistent with observations in more southerly locations. Big brown bats are often detected acoustically but not captured (Wilkinson *et al.* 1995; Kaupas pers. comm. 2015). The long-eared myotis typically comprises approximately 9% (range: <1 to 16%) of bats observed in published survey efforts elsewhere. However, in Alberta, capture composition has been upwards of 53% (described *in* Barclay 1991; Buseck and Keinath 2004). Since the long-legged myotis is typically found at higher elevations (Warner and Czaplewski 1984), search effort in the NWT, which has been concentrated in the relatively flat South Slave region, may be biased towards other species.

Since bats disperse across the landscape in spring, it is difficult to estimate summer population size. Winter censuses have been done at SSR-1 since 2011 and SSR-2 since its discovery in 2014. These winter hibernacula surveys report an average of approximately 2,900 over-wintering *Myotis* (little brown and/or northern myotis) at SSR-1 and 700 at SSR-2 (Cox pers. comm. 2015). Overall population size in the NWT is likely much larger than this, since little brown myotis and northern myotis are widely distributed in the South Slave and Dehcho regions and there may be undiscovered hibernacula. It is also possible that bats from adjacent provinces or territories (e.g., Walk-in Cave, Alberta; Reimer *et al.* 2014) forage and roost in the NWT during summer and vice versa.

Trends and fluctuations

In the NWT, winter surveys performed each year between 2011 and 2015 indicate a stable population of *Myotis* (little brown and northern myotis) at the SSR-1 hibernaculum, with slight annual fluctuations around a population of about 2,900 bats (Cox pers. comm. 2015). Since SSR-2 is a recently discovered hibernaculum, there have not been enough annual surveys to assess past or future population trends.

Current data are insufficient to assess population trends and fluctuations for the big brown bat, long-eared myotis, and long-legged myotis.

Bat monitoring and research is ongoing in the NWT and new populations of little brown and northern myotis continue to be discovered via acoustic monitoring, targeted mist-netting surveys and observation reports.

The International Union for the Conservation of Nature's (IUCN) Red List reported in 2008 that the global population trend for the big brown bat was 'increasing' (Miller *et al.* 2008). This assessment was based on the idea that increasing numbers of human habitations provide more habitat for big brown bats; however, the recent impact WNS has had on this species was not considered (see *Threats and limiting factors – emerging disease*, p. 73, for more information).

Prior to large-scale impacts from WNS, population trends for little brown and northern myotis were believed to be generally stable or increasing (Arroyo-Cabrales and Álvarez-Castañeda 2008b, c; Kunz and Reichard 2010; Olson *et al.* 2011; COSEWIC 2013). It is reasonable to expect that similar trends may persist regionally in areas that have not yet been affected by WNS. However, given the recent and rapid devastation in populations due to WNS, more recent assessments for little brown and northern myotis clearly show decreasing populations in WNS-affected areas and at the national and global scales (Kunz and Reichard 2010; COSEWIC 2013; USFWS 2015; see *Threats and limiting factors – emerging disease*, p. 73).

The IUCN Red List reported long-eared and long-legged myotis global population trends as stable in 2008; these species have not yet been affected by WNS (Arroyo-Cabrales and Álvarez-Castañeda 2008a, d).

Population dynamics

Calculating a 'generation time' (the average age of parents to young of the year) gives insight into the turnover rate of breeding individuals in the population. Accurate average lifespan and survivability rates are not prevalent in the literature and vary across regions due to environmental factors and climate (see *Life cycle and reproduction*, p. 51). Due to these limitations, generation time was estimated using a combination of two IUCN (2014) methods based on maximum age (for which there are better estimates). Using the median age of longevity method (maximum lifespan divided by two to estimate median age minus one year to account for non-breeding during the first year (the sub-adult period)), generation time was calculated as: 8.5 years for big brown bats, 16.5 years for little brown myotis, 8.5 years for northern myotis, 7.0 -10.0 years for long-eared myotis, and 9.5 years for long-legged myotis. The median age of longevity method most likely overestimates generation time for each species as survivorship decreases with age and few individuals may actually survive to maximum age (unpubl. data *in* COSEWIC 2013). Therefore, generation time was also calculated using a method that incorporates reproductive lifespan, survivorship, and first age of reproduction (see *Appendix A*, p. 119 for details). Using this method, generation times for each species were calculated as: 6.8 years for big brown bats, 11.1 years for little brown myotis, 6.8 years for northern myotis, 7.6 years for long-eared myotis, and 7.3 years for long-legged myotis.

Without reliable data on survival and reproduction rates, it is difficult to derive an accurate calculation. Given the use of maximum lifespan in each of the two methods described above, and the high maximum lifespan of little brown myotis, it is possible that the estimated generation time for this species is an overestimate. COSEWIC (2013), using both median age of breeding/longevity and the mean age that a cohort breeds, determined that a plausible estimate for generation time for little brown myotis is a range of 5-10 years.

By considering these different calculation methods together, it is possible to consider generation time as a range rather than a discrete value, which may provide more information. Generation time ranges for each species are reported as: 8-8.5 years for big brown bat 5-16.5 years for little brown myotis, 6.8-8.5 for northern myotis, 7.6-10.0 for long-eared myotis, and 7.6-10.0 years for long-legged myotis.

Data are inadequate to estimate birth rate, recruitment rate, death/survival rate, immigration rate, and emigration rate for any of the five species. Reproductive rates, sex ratio, and age structure is addressed in *Life cycle and reproduction*, p. 51.

Possibility of rescue

If population declines for the five bat species occur due to an NWT-specific factor (e.g., destruction of an NWT winter hibernation site), it is highly likely that individuals from adjoining provinces could immigrate and repopulate the area. Little brown myotis in particular are known to travel up to 647 km between summer and winter roosts (Norquay *et al.* 2013; see *Movements*, p. 51) and there are no geographic features that would prohibit movement into the NWT from provinces farther south. In addition, continental genetic analysis of little brown myotis suggests gene flow between bats in the Fort Smith area and Alberta (Wilder 2014).

During summer, reproductive populations of little brown myotis, northern myotis, and big brown bats are found in northern Alberta, and all five species of interest are found in northeast British Columbia (of which at least the four *Myotis* species are reproductive) (Wilkinson *et al.* 1995; Vonhof *et al.* 1997; Vonhof and Hobson 2001; Grindal *et al*. 2011; Reimer 2013). Reproductive populations of little brown and northern myotis can also be found in the Yukon (Lausen *et al*. 2008; Slough and Jung 2008).

During winter, approximately 100 bats, including little brown myotis and likely northern myotis and big brown bats as well, hibernate at Walk-in Cave, immediately south of the NWT in Wood Buffalo National Park (Reimer *et al*. 2014). Despite the small size of that particular hibernaculum, it is a karst-rich area that likely provides over-wintering habitat for additional congregations. In southern Alberta, there are two additional known hibernacula; Cadomin Cave (approx. 670 km from the NWT) and Wapiabi Cave (approx. 830 km from the NWT; Schowalter 1980). Cadomin Cave houses between 368-805 bats per winter, including little brown myotis, northern myotis, and long-legged myotis (Olson *et al.* 2011). Very small hibernacula of big brown bats and little brown myotis have been observed in British Columbia (Nagorsen *et al.* 1993); there are no known hibernacula in the Yukon. In general, known hibernacula are considered to be a small subset of the hibernacula that must exist on the landscape. Very few studies have documented hibernation habitat or hibernation location for long-eared myotis throughout their global range. Known locations include caves in northwestern California, Oregon, and Washington (Marcot 1984; Perkins *et al.* 1990; Navo *et al*. 2002; Hendricks 2012) with no observations recorded for provinces and territories adjacent to the NWT.

Since individuals exhibit strong site fidelity for both summer roosts and winter hibernacula (Navo *et al.* 2002; Olson *et al.* 2011), it may take time for new populations to establish themselves in the NWT; however, the current occurrence of bats in the NWT suggests that the current environment would be suitable for any immigrants that arrived. Since hibernation and maternity roost environments are similar across each species' range, individuals from elsewhere should be able to survive and reproduce in the NWT.

If population declines occur due to the arrival of WNS (see *Threats and limiting factors*, p. 73), it is most likely that the adjoining provinces (e.g., Alberta and British Columbia) will also be infected with *Pseudogymnoascus destructans* (*P. destructans*) and will be experiencing the same population losses, limiting the amount of 'rescue' possible. The *P. destructans* fungus can persist in the absence of bats for a long time, which may also prevent the successful recolonization of infected hibernation sites following a decline or extirpation (Hoyt *et al.* 2015).

Habitat

Habitat requirements

All five species are forest dwelling bats that have seasonally-dependent primary habitat requirements that include: 1) summer roost and foraging habitat and 2) autumn mating and winter hibernation sites. During summer, reproductive females form summer maternity colonies that vary in size and location by species, while males and non-reproductive females typically roost alone or in smaller groups elsewhere (Davis and Hitchcock 1965; Rabe *et al*. 1998; Solick and Barclay 2006; Rancourt *et al.* 2007; Johnson *et al*. 2011). Maternity roosts are used repeatedly over many years, allowing for information transfer and social interaction. Roost choice varies among species, but roosts can often be found in tree cavities and behind flaking bark, in rock crevices, and in buildings (Fenton and Barclay 1980; Barclay and Brigham 1996; Caceres and Barclay 2000; Norquay *et al*. 2013). *Myotis* species tend to prefer large standing dead or dying trees located in open areas in old growth forest for tree roosts (Jung *et al*. 2014).

Winter hibernation allows for reduced energy expense during periods of low/absent prey abundance. Most known hibernation sites are caves or abandoned mines, but overwintering in rock crevices, buildings, trees, and small cavities in scree fields and tree root wads has also been documented. There are few known hibernacula in western Canada (COSEWIC 2013) and little is known about overwintering strategies of bats in the northwest part of the country (Jung *et al.* 2014). The two known hibernacula in the NWT (SSR-1 and SSR-2) are naturally-formed underground caves. They are relic or inactive river caves that formed when underground water dissolved layers in the gypsum karst bedrock, after the retreat of the continental ice sheet approximately less than ten thousand years ago (Kelly pers. comm. 2016). There is an unconfirmed report of approximately 200 bats overwintering in the roof of a cabin in the South Slave region of the NWT (Wilson *et al*. 2014), but the species and fate of the bats are unknown.

Hibernation sites have high relative humidity (>80%) and stable, cool temperatures (2-12°C; Kunz and Reichard 2010) (Rysgaard 1942; McManus 1974; Nagorsen *et al.* 1993; Webb *et al.* 1996; Speakman and Thomas 2003; Lausen and Barclay 2006b; Vanderwolf *et al.* 2012; Jung *et al.* 2014; Blejwas *et al*. 2015). Hibernacula temperatures recorded in the NWT and in Wood Buffalo National Park, Alberta are at the low end of this temperature range and colder than those further south. SSR-1 hibernaculum has a recorded temperature range of 2.50-2.75°C and 100% relative humidity during the winter (Kelly unpubl. data 2013) and winter temperature in Walk-in Cave, Wood Buffalo National Park, fluctuated between -1.1 and 0.8°C (Reimer *et al.* 2014) (see *Physiology and adaptability*, p. 38 for more information on hibernacula temperatures).

During autumn, prior to hibernation, all five species have been observed ‘swarming’ at winter hibernation sites (Fenton 1969; Schowalter 1980; Navo *et al*. 2002) (which, in addition to facilitating mating behaviour may allow for information transfer (Bogdanowicz *et al.* 2012)).

Bats typically forage in forest gaps and edges, along trails, and over still water and rivers, (Crampton and Barclay 1996; Grindal and Brigham 1999; Jung *et al.* 1999; Holloway and Barclay 2000; Broders *et al*. 2003; Patriquin and Barclay 2003). Larger areas cleared for farm fields, clear cuts, or as the result of large fires are generally avoided by *Myotis* species, perhaps to avoid the windier conditions characteristic of these cleared areas or because of their influence on prey abundance and risk of predation (Barclay and Brigham 1996; Grindal and Brigham 1999; Hogberg *et al*. 2002; Henderson and Broders 2008; Randall *et al.* 2011).

With respect to habitat associations, age of a forest appears to be more important than type, with many bats, including little brown and northern myotis (Crampton and Barclay 1996; Sasse and Pekins 1996; Jung *et al*. 1999; Broders *et al*. 2005; Henderson *et al*. 2008; Park and Broders 2012), preferring old growth forests (Barclay and Brigham 1996).

Species-specific habitat requirements are described in more detail below. See *Interactions*, p. 55 and *Movements*, p. 51 for more information on foraging methods (aerial hawking and gleaning), intra- and interspecific interactions, and roost-switching.

Big brown bat

Throughout its range, reproductive females typically form maternity colonies of 5-75 individuals in human-made structures, tree cavities, and rock crevices (Davis and Hitchcock 1965; Kurta and Baker 1990; McAlpine *et al.* 2002; Lausen and Barclay 2006a; Neubaum *et al.* 2006; Rancourt *et al.* 2007). Proximity to water (e.g., within 0.8-1.8 km in Ohio; Mills *et al*. 1975) and foraging sites (Brigham 1991) are important qualities for these roosts. Both reproductive and non-reproductive individuals change roosts frequently throughout the season (Lausen and Barclay 2002; Metheny *et al*. 2008). As an aerial hawker (see *Interactions*, p. 55), big brown bat foraging sites are typically over open sites that include (but are not limited to) standing water, riparian areas, and forest (van Zyll de Jong 1985; Brigham and Fenton 1991; Agosta 2002; Owen *et al.* 2003; Ratcliffe *et al*. 2006). Foraging typically takes place high in the air, over the treetops rather than below the canopy (van Zyll de Jong 1985). Winter hibernation sites consist primarily of caves (Griffin 1940; Rysgaard 1942; Beer and Richards 1956), in which big brown bats tend to prefer colder, more exposed areas than do *Myotis* species (Griffin 1940). Preferred cave conditions have been reported as 1.7-9.5°C (35-49°F) with humidity of 67-92% (Rysgaard 1942; Perry 2013). Rock crevices are used for hibernating in the Canadian prairies (Lausen and Barclay 2006b). Occasionally, big brown bats are observed hibernating in human-made structures (Mills *et al.* 1975; Perkins *et al.* 1990; McAlpine *et al*. 2002; Neubaum *et al*. 2006).

Little is known about big brown bat habitat use in the NWT. There are no recorded observations of big brown bats roosting in buildings, and no summer roosts of any type have been located or described in the NWT (Wilson pers. comm. 2015). In the South Slave region, the big brown bat has been observed flying around beaver ponds during summer and using the SSR-1 hibernaculum during winter (Kelly unpubl. data 2013; Reimer unpubl. data cited *in* Wilson *et al.* 2014). Individuals were not observed roosting on walls in the main chambers (where temperature recorders were located) during winter surveys, which may suggest that they are using cracks and crevices with different microclimates than open chambers. There is also some evidence of big brown bats overwintering in a limestone cave in Wood Buffalo National Park, Alberta, possibly in crevices created by rock slabs (Reimer *et al.* 2014).

Little brown myotis

Throughout its range, reproductive females form much larger maternity colonies than the other five bat species considered in this report. Group sizes of hundreds of individuals are often observed. Maternity colonies are most often observed in human-made structures (Smith 1940; Anthony and Kunz 1977; Jung 2013; Randall *et al*. 2014). Past research has typically targeted colonies in buildings, and the potential importance of tree roosts to reproductive females has yet to be determined; it is possible that natural roosts may predominate in remote parts of their range (COSEWIC 2013). Old growth forests may provide ample roosting habitat (Crampton and Barclay 1996; Krusic *et al.* 1996; Jung *et al.* 1999). Females exhibit strong site fidelity across years (Davis and Hitchcock 1965; Norquay *et al*. 2013). Summer roosts for males and non-reproductive females typically consist of rock cliffs, trees, and buildings (Randall *et al*. 2014); occasionally, males may use hibernacula as day roosts during the summer (Davis and Hitchcock 1965; Reimer *et al*. 2014). Little brown myotis typically forage (using both hawking and gleaning; see *Interactions*, p. 55) in areas of limited clutter such as along trails, over water bodies (e.g., beaver ponds), and along forest edges (Adams 1996, 1997; Krusic *et al.* 1996). Winter roost conditions typically observed in little brown myotis hibernacula (mines and caves) include temperatures from -4ºC to 13ºC (Webb *et al.* 1996) and a relative humidity between 73-100% (Rysgaard 1942; Perry 2013). Little brown myotis in Alaska have been observed hibernating in small cavities in scree fields and tree root wads (Blejwas *et al.* 2015).

In the NWT, maternity colonies have been documented in building attics and large artificial bat house structures, with populations of approximately 100-400 individuals (Fig. 20, p. 66; Reimer 2013; Wilson *et al.* 2014). During July, the period of greatest summer bat activity, daily temperature within a main maternity roost (Fig. 20a, p. 66) averaged 21.7ºC (min: 10.2, max: 39.4) (Reimer unpubl. data 2013b). Males and non-reproductive females have been observed roosting under exfoliating bark on trees, under the wood siding of buildings, and using the SSR-1 cave hibernaculum during summer (Wilson *et al.* 2014). Little brown myotis have been captured and observed foraging at open ponds and creeks, and above grassy fields and cutlines (Reimer unpubl. data 2012; Lausen *et al.* 2014), which is consistent with more southerly observations (e.g., foraging over ponds; Barclay 1991). Little brown myotis has been observed in summer at higher elevations in the Nahanni region than the other *Myotis* species (Lausen *et al.* 2014). The little brown myotis is the most commonly observed species in winter cave hibernacula in the NWT (SSR-1 and SSR-2) and farther south in Wood Buffalo National Park, Alberta (Reimer *et al*. 2014).

Figure 20. Maternity roots of little brown myotis (*Myotis lucifugus*) in buildings at (a) Thebacha cabin, and (b) at Lady Evelyn Falls campground and in (c, d) artificial 'bat boxes' (photo credit: J. Reimer).

Northern myotis

Throughout their range, reproductive females form maternity colonies in small groups (e.g., 11-65 individuals). Maternity roosts are typically in tree cavities and under exfoliating bark (Foster and Kurta 1999; Menzel *et al.* 2002; Timpone *et al*. 2010; Johnson *et al*. 2011). Reproductive females exhibit strong fidelity to maternity roosts year after year (Arnold 2007). In Canada, the northern myotis is generally associated with boreal forests (Nagorsen and Brigham 1993). Undisturbed forest is important for both roosts and foraging, with individuals typically foraging under closed canopy rather than the less-cluttered habitat associated with little brown myotis (Carter and Feldhamer 2005; Broders *et al.* 2006; Henderson and Broders 2008). Northern myotis have also been observed using roads and open forest corridors that may provide a semi-open edge for easy travel and prey capture (Owen *et al*. 2003; Kaupas pers. comm. 2015). Winter hibernation occurs in caves similar to little brown myotis with temperatures ranging from 0.6-13.9°C and relative humidity of 65% (summarized *in* Webb *et al.* 1996; Caceres and Barclay 2000; Perry 2013; Randall and Broders 2014).

In the NWT, two northern myotis maternity colonies have been studied in the Fort Smith area with the colony size ranging from 25-47 individuals (mean 38.1) (Kaupas 2015); this is the largest mean colony size reported in the literature (with Menzel *et al*. (2002) reporting the next largest mean colony size (31.3 ± 16.9 individuals)). Based on observations at 26 maternity roost trees, lactating northern myotis in these colonies roost in cavities or cracks of mature trembling aspen (*Populus tremuloides*) (Fig. 21, below; Reimer and Kaupas 2013; Kaupas 2015). Other deciduous tree species such as balsam poplar (*Populus balsamifera*) may be used in other places if available (Vonhof *et al*. 1997; Olson et al. 2011; Kaupas 2015). Roost trees used by colonies in the Fort Smith area are of large diameter (diameter at breast height ranging from 17.4-38.8 centrimetres (cm), average 28.2 cm) and in various states of decay, but most are alive or recently dead. Roost trees are in areas with relatively dense understories, which may be important for foraging habitat (Kaupas 2015). Reproductive females frequently move between day roosts yet do not travel far (average 230 meters (m) between roosts; Kaupas 2015). Northern myotis have been captured in the NWT at beaver ponds, creeks, and along narrow trails cutting through trembling aspen forests (Reimer and Kaupas 2013; Lausen *et al.* 2014; Wilson *et al.* 2014). Individuals have been observed entering and exiting the SSR-1 hibernaculum and Walk-in Cave in Wood Buffalo National Park, Alberta, suggesting that they may overwinter in these caves (Reimer unpubl. data 2013a; Reimer *et al.* 2014).

Figure 21. Two typical northern myotis roosts in the Fort Smith colony (left photo shows a frost crack roost, right photo shows a cavity roost). The orange arrows show roost entrance (reprinted with permission from Laura Kaupas).

Long-eared myotis

Throughout its global range, reproductive females form relatively small maternity colonies of fewer than 30 individuals (Nagorsen and Brigham 1993; Kunz and Lumsden 2003; Rancourt *et al.* 2005; Solick and Barclay 2006; AESRD 2015) in snags and stumps, rock crevices, and human-made structures (Chruszcz and Barclay 2002; Manning and Jones 1989; Rabe *et al*. 1998; Rancourt *et al.* 2005; Solick and Barclay 2006; Vonhof and Barclay 1996, 1997). They exhibit frequent roost switching (Vonhof and Barclay 1996; Rancourt *et al*. 2005) yet distances between roosts are relatively short (<400 m) and colonies generally display high fidelity to patches of habitat (Rancourt *et al*. 2005; Solick and Barclay 2006; Nixon *et al.* 2009). Non-reproductive females have been observed roosting alone in slightly cooler roosts with more stable microclimates than reproductive females; the same is probably true for males (Solick and Barclay 2006). Long-eared myotis are found in a variety of habitats, including coniferous and mixed forests, humid coastal areas, montane forest, arid grasslands and prairie river valleys (Manning and Jones 1989; Chruszcz and Barclay 2002; Solick and Barclay 2006) and within a wide range of elevations, from sea level to approximately 2,050 m (Nagorsen and Brigham

1993). They typically forage near dense vegetation, in forested areas, and along paths within forests (Barclay 1991). Few documented records exist for long-eared myotis during hibernation. They have occasionally been observed hibernating in caves (Cross 1977; Marcot 1984; Perkins *et al.* 1990) and have also been observed at a swarming site (cave) in Colorado along with little brown and long-legged myotis (Navo *et al*. 2002).

Little is known about long-eared myotis habitat use in the NWT. This species has been recorded along the South Nahanni watershed, an area that has an abundance of rocks, trees, and standing water and is surrounded by high canyon walls (described *in* Lausen 2006). No observations have been made regarding long-eared myotis foraging habitat, roost use or hibernation sites in the NWT.

Long-legged myotis

Throughout their range, reproductive females form relatively large maternity colonies of 100-500 individuals in rock cracks, snags, and buildings, and may share roosts with little brown myotis (Dalquest and Ramage 1946; Quay 1948; Davis and Barbour 1970; Baker and Lacki 2006). Females using natural roosts often move between roosts throughout the summer (Baker and Lacki 2006). Summer roosts for males and non-reproductive females are primarily in coniferous forest (summaries *in* Warner and Czaplewski 1984), where they use a variety of natural roosts such as snags, exfoliating bark, rock crevices, cracks in the ground, and occasionally abandoned buildings (Dalquest and Ramage 1946; Quay 1948; Baker and Phillips 1965; Vonhof and Barclay 1996; Ormsbee and McComb 1998; Baker and Lacki 2006; Johnson *et al.* 2007). Foraging occurs in a variety of habitats including cluttered habitats such as riparian forest and under the forest canopy, as well as uncluttered, open habitats (Bell 1980; Fenton and Bell 1981; Humes *et al.* 1999; Saunders and Barclay 1992). Long-legged myotis have been observed hibernating in caves with other *Myotis* species and there is strong fidelity to hibernation sites (Cross 1977; Navo *et al*. 2002; Olson *et al.* 2011).

Relatively little is known about long-legged myotis habitat use, including in the NWT. This species was captured in the South Nahanni watershed, an area that has an abundance of rocks, trees, and standing water, and is surrounded by high canyon walls (described *in* Lausen 2006). No observations have been made regarding long-legged myotis foraging habitat, roost use or hibernation sites in the NWT.

Habitat availability

Habitat availability for bats in the NWT has not been quantified; however, both the boreal forest and karst formations (landscape area rich in soluble minerals that is often characterized by caves and sinkholes) are important habitat for the five species of interest; in particular, big brown bats, little brown myotis, and northern myotis. The boreal forest provides summer roosts and foraging habitat while caves (potential winter hibernacula) are often found in karst habitat (see *Habitat requirements*, p. 62, for other possible types of hibernation habitat).

The boreal forest covers approximately 614,000 km^2 of the NWT (Bohning *et al.* 1997; Fig. 22, p. 71). It is unknown how much of the boreal forest is inhabited by bats, but it may be considered 'potential habitat' for the wider ranging species such as little brown and northern myotis that appear to have fewer geographical restrictions in the NWT compared to long-eared and long-legged myotis. Wilson *et al*. (2014) suggested that much of the southern Taiga Plains ecoregion (Fig. 6, p. 32) contains suitable habitat for bats, whereas the Taiga Shield supports some bats but is expected to be less suitable due to its cooler climate and more open, stunted forest. The Taiga Cordillera ecoregion also supports bats. Across ecoregions, habitat suitability for bats may reach a northern limit below the treeline due to climate (temperature and summer length) and/or availability of summer roosts (e.g., suitable trees) (Wilson *et al.* 2014).

Karst formations are found throughout the NWT, with the majority of karst habitat existing in the Sahtú region, southern Nahanni National Park Reserve (NNPR), and the Wood Buffalo National Park area of the South Slave region (Fig. 22, p. 71; Ford 2008, 2009; Wood Buffalo National Park unpubl. report 1981). Some caves in NNPR and the South Slave region have been explored but few have been investigated in winter to determine whether they are used by bats (Scotter *et al*. 1971; Fenton *et al.* 1973; Cox pers. comm. 2015). However, a large amount of little brown myotis activity has been observed at caves in NNPR in late summer, suggesting the possibility of winter use (Fenton *et al.* 1973), and a sighting of bats reported west of Tulít'a in March suggests that hibernacula could also be found in the Sahtú region (Wilson *et al.* 2014). Further exploration of karst terrain, and investigation of known caves in winter, could identify additional hibernacula. In addition, there are numerous abandoned mines around the NWT that may act as potential roosts and/or hibernacula (Davis and Hitchcock 1965; Thomas *et al.* 1979; Nagorsen *et al*. 1993; Northwest Territories Geoscience Office 2013).

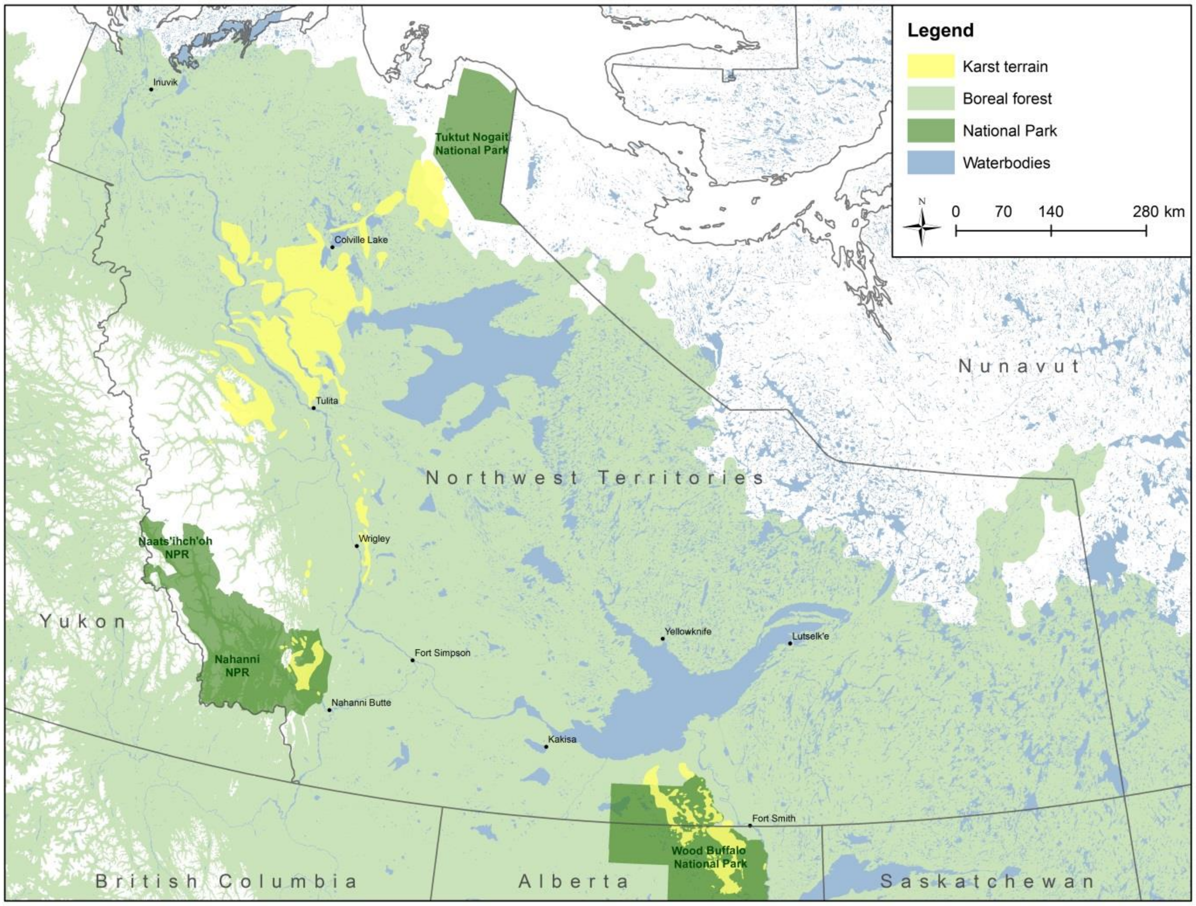

Figure 22. Potential summer (boreal forest) and winter (karst) habitat for hibernating bat species in the NWT as delineated by Brandt (2009), Ford (2008, 2009), and Wood Buffalo National Park (unpubl. report. 1981). Map created by J. Reimer (AKNHP) with permission from the NWT Protected Areas Strategy (www.nwtpas.ca) and Wood Buffalo National Park.

Habitat fragmentation and trends

In the NWT, the boreal forest is a continuous, large, dynamic mosaic of habitat types including early successional forest stages important for foraging and older forests important for roosting; this mosaic is maintained and renewed by fire. Forest bat species are presumably well-adapted to this dynamic habitat (Loeb and O'Keefe 2011). At a local scale, forest fires may cause temporary fragmentation, displacement, and/or destruction of bat roost and foraging habitat (Fig. 23, p. 72; Johnson *et al*. 2012). Fisher and Wilkinson (2005) reviewed the response of small mammals, including bats, to forest fires and regrowth throughout the boreal forest of North America. They suggested that while bats may use recently burned areas (<10 years) for occasional foraging, a lack of roost sites results in low bat activity until a forest reaches the old growth stage (76 to >125 years). Conversely, numerous studies focusing on northern myotis have observed an increase in roost availability (e.g., snags) after a burn (Boyles and Aubrey 2006; Johnson *et al.* 2009; Lacki *et al.* 2009). In addition, immediately following a burn, an increase in insect (prey) abundance was observed (Lacki *et al.* 2009).

Forest fires disturb an average of 600,000 hectares (ha) of NWT forest annually (Fig. 23, below; ENR 2015e). The annual total area burned fluctuates each year, but a weak trend indicates a slight reduction in both total area burnt and the number of fires larger than 200 ha between 1988 and 2008 (ENR 2015e). This does not account for the particularly severe fire season seen in the NWT in 2014 where 385 fires impacted approximately 3.4 million ha (ENR 2014a). Short and long-term impacts from this fire season have yet to be assessed. It is predicted that climate change will result in an increase in the frequency and intensity of fires, due to hotter, drier summers that provide a long fire season (Soya *et al.* 2007).

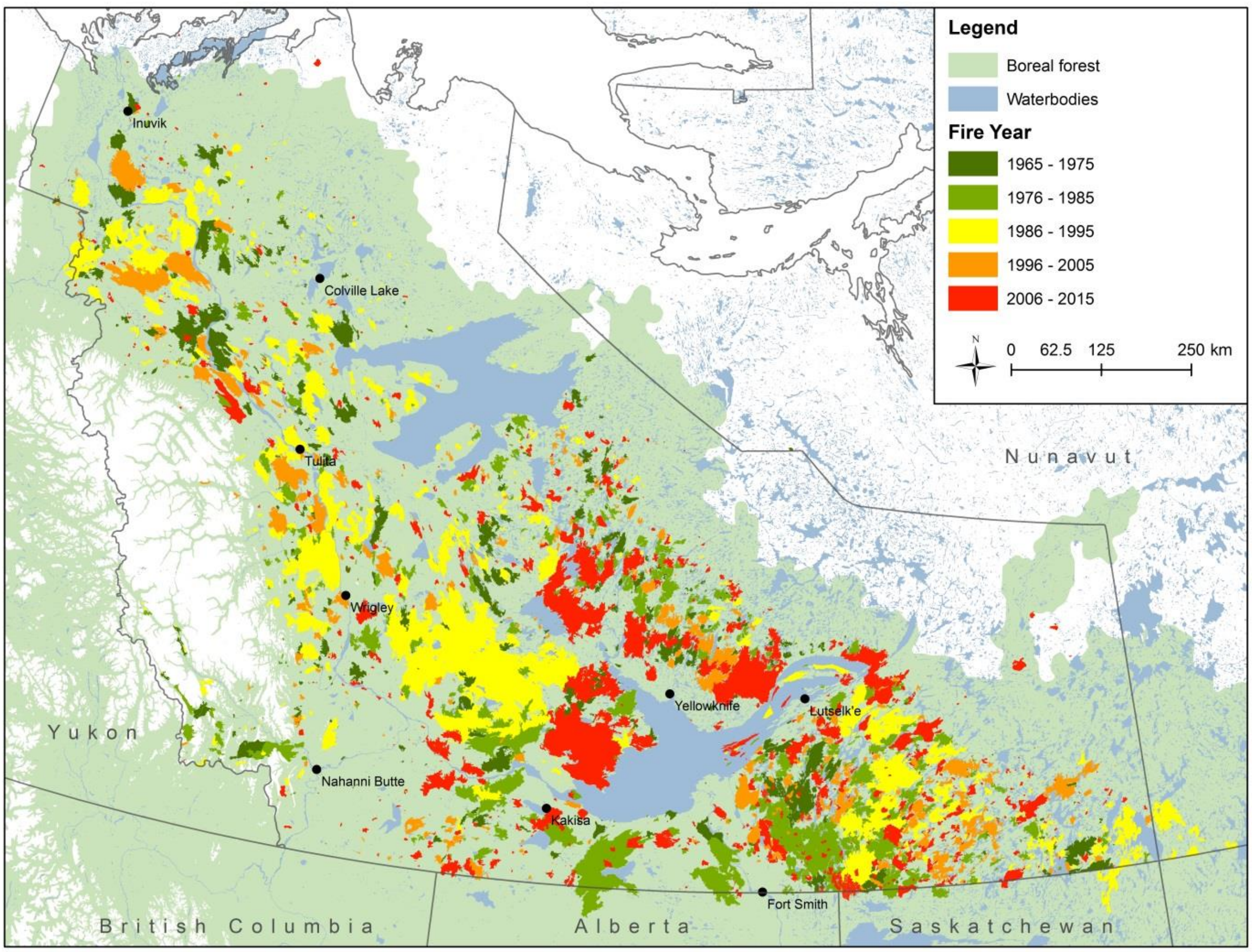

Figure 23. Fire history (1965-2015) throughout the NWT. Map created by J. Reimer (AKNHP) using GNWT datasets (Center for Geomatics 2015).

In the NWT, the boreal forest is relatively undisturbed by human activities compared to southern Canada. Seismic lines are the largest anthropogenic landscape disturbance in the NWT (ENR 2015e). They are often considered an agent for habitat fragmentation and can have negative impacts on local forest-dwelling animals, such as boreal caribou (Dyer *et al.* 2002). Many bat species however, forage along linear features such as trails and roads (e.g., Krusic *et al.* 1996; Owen *et al*. 2003) and radio telemetry studies in the Fort Smith area have observed both little brown and northern myotis travelling and foraging along power lines (Reimer unpubl. data 2012; Kaupas pers. comm. 2015). Timber harvest has varying degrees of impact depending on the species (Pauli *et al*. 2015). The most recent NWT Biomass Energy Strategy (ENR 2012:1) states that one of the objectives is to “Increase the use of biomass fuels, such as cord wood, wood chips and pellets, in all segments of the NWT space heating market”, suggesting that an increase in timber harvesting will continue to be promoted in the NWT (see *Threats and limiting factors*, p. 73 for more details).Ethier and Fehrig (2011) suggested that forest fragmentation (independent of forest amount) can benefit little brown and northern myotis by allowing access to foraging sites from roosting sites.

Changes to the boreal forest associated with climate change could affect roosting and foraging and hibernation habitat, prey availability, and reproductive success. In the last 15 years, the NWT has generally been experiencing a warmer climate compared to records from 1961-1990. This is particularly pronounced in the winter (December-February) in the Taiga Plains ecoregion. The Mackenzie District as a whole (encompassing all forested areas of the NWT) has seen the largest winter temperature increase in Canada; increasing by 4.5ºC between 1948-2011. Changes in growing season have also been observed throughout the NWT. In the Taiga Cordillera, Taiga Plains, and western Taiga Shield, spring is arriving earlier and the growing season has lengthened by between 9-28 days (ENR 2015e).

Distribution trends

Distribution trends for these species are unknown.

THREATS AND LIMITING FACTORS

Emerging disease – white-nose syndrome

White-nose syndrome (WNS) is considered the most devastating disease for many cave-hibernating bat species in North America (Frick *et al.* 2010b) and is caused by the fungus *Pseudogymnoascus destructans*. *P. destructans* likely arrived in North America from Europe, where it is known to occur on bats, although without the same devastating mortality (Lorch *et al.* 2013). WNS currently affects big brown bats, little brown myotis, northern myotis, and several other hibernating bat species (Blehert *et al.* 2008), and is estimated to have resulted in the deaths of more than 5.7 million bats throughout North America (USFWS *et al.* 2016). It prompted the emergency assessment (2013) and listing (2014) of little brown myotis, northern myotis and the tri-coloured bat (*Perimyotis subflavus*) as endangered in Canada (COSEWIC 2013; Species at Risk Public Registry 2015) and the listing (2015) of northern myotis as threatened in the United States (USFWS 2016).

Since its initial discovery in New York during winter 2006/2007, WNS has spread rapidly and now occurs throughout most of the northeastern U.S. and southeastern Canada. The discovery on March 11, 2016 of WNS in the Pacific northwest however (Fig. 24, below), substantially extends its North American range. Although it is likely that this new western occurrence is of North American origin (rather than being introduced independently from Europe), how it reached this far west, 2,100 km away from the next nearest occurrence in Nebraska, has not yet been determined. This new western occurrence has important implications for management, as it does have the potential to accelerate the western spread of WNS (Lorch *et al*. 2016). As noted by Lorch *et al.* (2016: 4), “The severity, magnitude, duration, and potential ecosystem-level effects of WNS in North America rank it among the most consequential wildlife disease events ever recorded.”

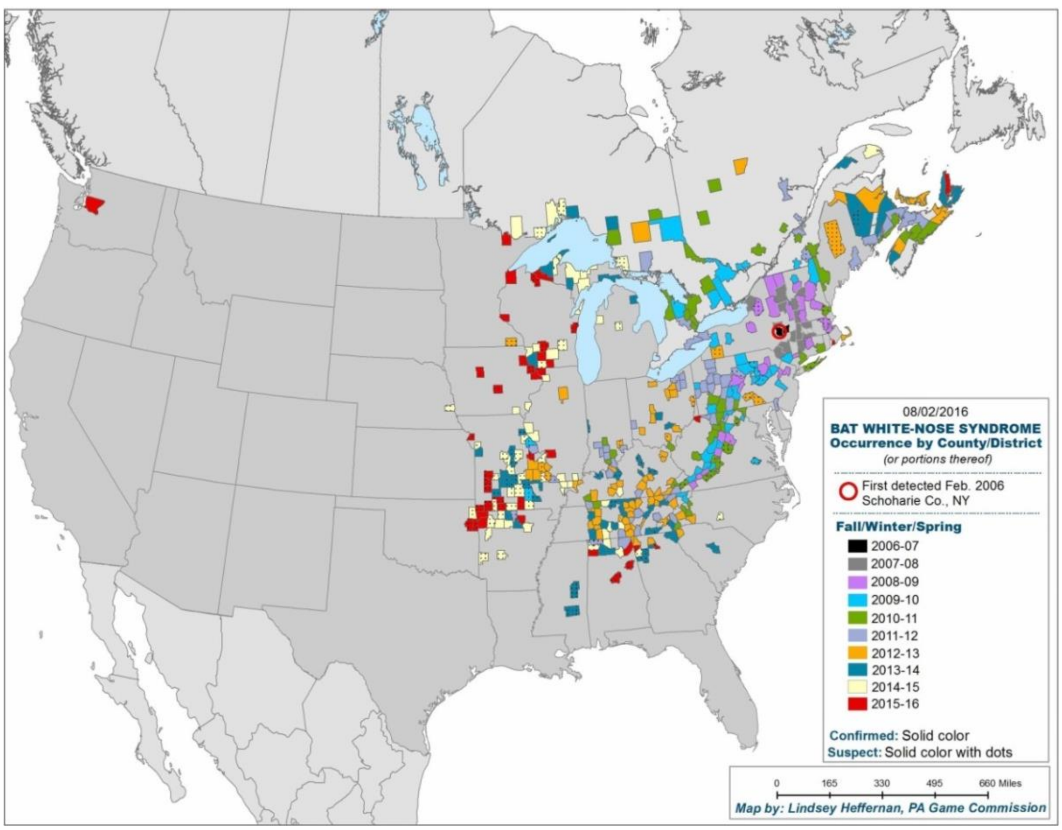

Figure 24. The range of bats affected by WNS in North America as of August 2, 2016 (map produced by Pennsylvania Game Commission, obtained from USFWS *et al.* 2016). This map is frequently updated and available

online: www.whitenosesyndrome.org).

The WNS fungus grows in relatively warm, moist caves (optimal growth: 5-15.8ºC, growth range: 0-19ºC; Blehert *et al*. 2008; Verant *et al.* 2012), similar to the hibernacula conditions preferred by hibernating bats (Perry 2013). It is transferred between substrates in numerous ways, including from bat to bat, from cave substrate to bat, and from bat to cave substrate, as well as by humans between sites (Coleman and Reichard 2014), and can survive in caves for long durations in the absence of bats (Lorch *et al.* 2013; Hoyt *et al*. 2015).

It creates a cutaneous infection (infection of the skin) in bats and disrupts their torpor patterns during winter, which depletes fat reserves and potentially causes dehydration, resulting in death (Willis *et al.* 2011; Frank *et al.* 2014; Verant *et al.* 2014). Fatality rates vary by bat species and are typically much greater for smaller bodied *Myotis* than big brown bats (Francl *et al.* 2012; Frank *et al*. 2014).

Infection of *P. destructans* at a hibernaculum usually results in severe population decline or extirpation. Four years after WNS was initially detected, annual decreases in bats at infected hibernacula averaged 74% (range 30-99%) and all surveyed sites had become infected within two years of the disease arriving in their region (Frick *et al.* 2010a). Most of these bats were little brown myotis. By 2012, virtually all known significant hibernacula in the northeastern U.S. were infected with WNS (Herzog and Reynolds 2012 *in* COSEWIC 2013). Average decline in six northeastern U.S. states after two years' exposure to WNS was 91% for little brown myotis (54 hibernacula, 12 of which declined to zero bats) and 98% for northern myotis (30 hibernacula, 23 of which declined to zero bats) (Turner *et al.* 2011).

Declines in eastern Canada where WNS has established have been similarly catastrophic. As of 2013, an overall decline of 94% in hibernating *Myotis* species was reported in Nova Scotia, New Brunswick, Ontario, and Quebec between the pre-WNS and post-WNS period (COSEWIC 2013; based on 93% (Ontario), 99% (New Brunswick), 93% (Nova Scotia) for *Myotis* species combined; and 98% for little brown myotis and 99.8% for northern myotis in Quebec). In addition, reductions of up to 80% in summer activity have been reported for little brown myotis (Dzal *et al.* 2011; Turner *et al.* 2011; Moosman *et al.* 2013) and 60-90% for numerous bat species, including northern myotis, in WNS-infected areas (Francl *et al*. 2012; Moosman *et al.* 2013). These reductions reflect the impact of WNS winter mortalities in these summer areas. Population dynamic models predict a 99% extinction of little brown myotis in northeastern North America by 2026 (Frick *et al*. 2010a), with equally devastating extinction rates for northern myotis (Langwig *et al*. 2012). Recent studies have shown that while fungal loads of *P. destructans* are relatively large on bats during hibernation, if individuals survive the winter, fungal loads begin to diminish as they migrate to their summer roost sites, with little to no fungal load remaining at the end of the summer (Langwig *et al.* 2015). Summer roost temperatures are typically greater than the upper threshold of *P. destructans* and provide a temporary reprieve for survivors from WNS.

WNS has not to date affected long-eared or long-legged myotis in the wild, primarily because the distribution of *P. destructans* did not until recently overlap with the distribution of these species. However, given the recent confirmation of WNS in the Pacific northwest (within the continental ranges of both the long-eared and long-legged myotis) (Lorch *et al.* 2016), their similar body size and physiology to other *Myotis* species currently affected by WNS, and their affinity for hibernating in caves, both the long-eared and long-legged myotis are considered to be at risk for WNS if exposed to the fungus (Western Bat Working Group 2014; Hayman *et al.* 2016).

Big brown bats are also affected by WNS but their survival rates have been shown to be greater than *Myotis* species when infected. This may be due to their larger body size, differing physiology during hibernation and use of drier and/or colder hibernation sites (Cryan *et al.* 2010; Langwig *et al.* 2012; Moosman *et al.* 2013; Hayman *et al.* 2016). Turner *et al.* (2011) estimated a 41% average decline in six northeastern U.S. states after two years' exposure to WNS. Langwig *et al*. (2012) found that population growth rate for big brown bats following WNS detection was not significantly different from zero, but was significantly lower than growth rates pre-WNS. Some studies report increased capture numbers for big brown bats in areas post-WNS (Francl *et al.* 2012; Frank *et al*. 2014).

Since the arrival of WNS in Canada, it has been expanding at an average rate of 200-250 km per year. If this rate continues, it will take approximately 12-18 years for WNS to reach the NWT (COSEWIC 2013). Recognizing the recent occurrence of WNS in the U.S. Pacific northwest, which did not follow the expected pattern of transmission, it is conceivable that WNS could spread to distant locations as far away as the NWT much sooner than 12-18 years. There is uncertainty about the rate of spread of WNS to western and northern Canada, including the NWT. It is largely unknown how the ecology of the disease may be affected by the amount of east-west bat movements, wintering ecology, and hibernacula conditions in these regions. However, there is evidence that conditions in known hibernacula are conducive to growth of the fungus and that hibernacula with lower bat densities are susceptible to WNS, and there is no evidence of containment to date (COSEWIC 2013).

In the NWT, the SSR-1 hibernaculum has a temperature range of 2.50-2.75°C and 100% relative humidity between November and July (Kelly unpubl. data 2013). These conditions are cooler than optimal growth conditions for *P. destructans*; however, they fall within the range of viable growth temperatures and bats exposed to WNS at <4°C in laboratory experiments still eventually died (Grieneisen 2011). In addition, an increased exposure period due to longer hibernation durations in the NWT (Reimer 2013) may negate any potential benefits of slower fungus growth and could actually result in higher mortality rates (COSEWIC 2013), although documented hibernation periods in the NWT do appear to be roughly comparable to those in more southerly locations (see *Physiology and adaptability*, p. 49). Model results suggest that WNS spread and mortality is most likely to occur in habitats that are drier and colder during winter (Flory *et al.* 2012), such as in the NWT.

Genetic studies suggest that little brown myotis populations in the west are smaller and more isolated than populations in the east (Wilder *et al.* 2015). In addition, bats in Canada west of the Rocky Mountains have different hibernation behaviour and likely hibernate singly or in small groups rather than large hibernacula (Nagorsen *et al*. 1993; Jung *et al*. 2014; Blejwas *et al*. 2015). This genetic isolation and the lack of large hibernacula as seen in the west could potentially slow the spread of WNS. Populations in the NWT however, use large hibernacula and have strong gene flow with the eastern populations (Alberta and Saskatchewan; Wilder 2014)

Some management and mitigation actions are already being implemented, including monitoring and surveillance programs (CWHC 2016) and mitigation of human fungus transfer through proper decontamination of gear (Shelley *et al.* 2011). Investigation into other plausible management and mitigation options is also ongoing. Other possible options include treatment of infected bats (Meteyer *et al.* 2011; Cornelison *et al.* 2014a; Cornelison *et al.* 2014b; Gabriel 2015), reduction of mid-winter starvation and dehydration in infected bats (Foley *et al.* 2011), and modifications to hibernation environments (Boyles and Willis 2010). In addition, small populations of surviving individuals are starting to be documented in areas initially infected with WNS; the mechanisms supporting survival are not known but could reflect the use of colder hibernacula microclimates by survivors, and/or differences in how these bats respond to the disease (Dobony *et al.* 2011; Reichard *et al*. 2014; Fishman 2015; Lilley *et al*. 2016).

Human impacts at hibernacula

Large, underground caves are of great interest to outdoor enthusiasts and explorers; however, human disturbance during hibernation can have negative impacts on bat health and survivability (Thomas 1993; Olson *et al.* 2011). Passive disturbance (entering the cave for research or recreational purposes) during hibernation can cause bats to arouse out of torpor and use up stored fat reserves, resulting in reduced fitness and potential starvation if repeatedly disturbed throughout the season (Speakman *et al.* 1991; Thomas 1995). Industrial activities in or near hibernacula that cause noise, light or vibrations can also disturb hibernating bats and cause them to arouse from torpor (Environment Canada 2015). In addition, active disturbance of bats can cause physical harm to the bats. Some caves in more southerly locations with high human traffic have gates to limit access when bats are present (i.e., winter hibernations; White and Seginak 1987), yet can still allow human exploration during summer when bats are absent.

In the NWT, the precise locations of winter hibernation sites are considered classified, and in an effort to reduce human traffic, are not readily shared with the public (Wilson pers. comm. 2015). Motion-sensor cameras were deployed at SSR-1 in 2013 to monitor human visitors and detected no human disturbance at the site (Cox pers. comm. 2015). Visits to SSR-1 and SSR-2 for research and monitoring purposes have been limited to once per winter or less (Kelly pers. comm. 2016).

Human activities that change hibernacula conditions (including accessibility, temperature, humidity, airflow, and hydrology) can have a negative impact on bats. This can include blocking or gating cave entrances, making modifications for tourists, decommissioning or reactivating mines, quarrying, or forestry activities that take place around hibernacula. Additionally, the use of heavy machinery (e.g., timber harvesting equipment) near weak areas of a hibernaculum could cause collapse (McAlpine 1983; Environment Canada 2015).

Exclusion and removal of maternity roosts

The effects of removing a maternity roost, or excluding bats from a roost (e.g., by sealing the entrances), depend on factors such as timing, species, and availability of other suitable habitat. Big brown bats and little brown myotis excluded from a maternity roost may move to new roosts (Brigham and Fenton 1986; Brittingham and Williams 2000), but this can affect the fitness of displaced bats, including reducing their reproductive success (Brigham and Fenton 1986). Neilson and Fenton (1994) found that breeding little brown myotis females abandoned the area after their building roost was sealed, and did not use other available roosts or join other colonies nearby.

If adult females are excluded (i.e., roost access is prevented) during the breeding season before their pups have fledged, juveniles will be left without food or hydration. This will most likely result in the death of all individuals inside the roost site, which could have a significant impact on local populations (Environment Canada 2015). These impacts can be avoided by sealing entrances during autumn after juveniles have fledged.

Many homeowners do not appreciate bats living in their attics and will often attempt to remove maternity colonies using non-lethal (exclusion) or lethal (extermination) methods. In the NWT, this threat is relevant primarily to little brown myotis as they are the only species documented using building roosts in the NWT thus far, although the other species are known to use building roosts elsewhere (see *Habitat requirements*, p. 62). Public education can reduce this threat as the general fear of bats is reduced and community members are informed of the appropriate time and methods for excluding bats from their houses. Erecting well-designed, well-placed bat houses nearby, to provide alternative roosts the year after exclusion, can also help bat colonies to relocate successfully (Brittingham and Williams 2000).

Removal of maternity roost trees may occur through timber harvesting, residential development, or any other development activity that requires clearing forested land. This threat is relevant to northern myotis in the NWT, including the maternity colony roosting in trees within the town of Fort Smith (Kaupas 2015). In a Kentucky forest where roosts were not limiting, northern myotis used different trees for roosting after their previous trees were removed outside the breeding season, and did not abandon the area or substantially change their roosting behaviour (Silvis *et al.* 2015). However, Silvis *et al*. (2015) cautioned that bats' tolerance to roost loss may depend on local forest conditions, including the availability of alternate roost trees.

Removal of occupied maternity roost trees during the breeding season would likely cause mortality, although data on this are lacking. Under section 5.7.2(V) of the Commercial Timber Harvest Planning and Operations Standard Operating Procedures, timber harvesting operations in the NWT are not currently permitted to occur during the migratory bird nesting season (May-August), which overlaps with the breeding season for bats (see *Physiology and adaptability*, p. 49).

Habitat loss and degradation – timber harvest

Timber harvest has varying degrees of impact on bat habitat depending on the species (Pauli *et al*. 2015). Forestry practices that lead to a decline in the amount of older age forests could have a negative impact, as many bat species are more abundant in the oldest forest stands. This is likely primarily related to the availability of snags and large live trees for roosting (Barclay and Brigham 1996; Crampton and Barclay 1996; Krusic *et al*. 1996; Sasse and Pekins 1996; Jung *et al.* 1999; Broders *et al.* 2005); these negative impacts can be reduced through selective harvest practices. Timber harvest also affects foraging habitat. *Myotis* bats generally avoid large areas of cleared land such as clear cuts (Hogberg *et al.* 2002; Owen *et al*. 2003; Patriquin and Barclay 2003); however, some bats use the edges of forest patches, regeneration areas and early successional forest as new foraging habitat (Hogberg *et al.* 2002; Loeb and O'Keefe 2006). Bats that forage primarily by aerial hawking like big brown bats are more likely to use the edges of clearcuts compared to bats that are more specialised for gleaning such as northern myotis (Patriquin and Barclay 2003). Selective harvest practices can assist bat conservation by leaving roost sites, such as tree snags, intact, and harvesting in a method that increases the amount of forest edge to facilitate travel and foraging (Taylor 2006; Pauli *et al*. 2015).

In the NWT, commercial timber harvesting has occurred in numerous places and is typically done by small-scale local businesses in localized areas and in small volumes (500-10,000 m^3 per year). The largest annual harvest since 1980 was in 1996 and totalled 144,461 m^3 (ENR 2015e) (Fig. 25, p. 80). Harvest species have been predominantly white spruce (*Picea glauca*) and jack pine (*Pinus banksiana*).

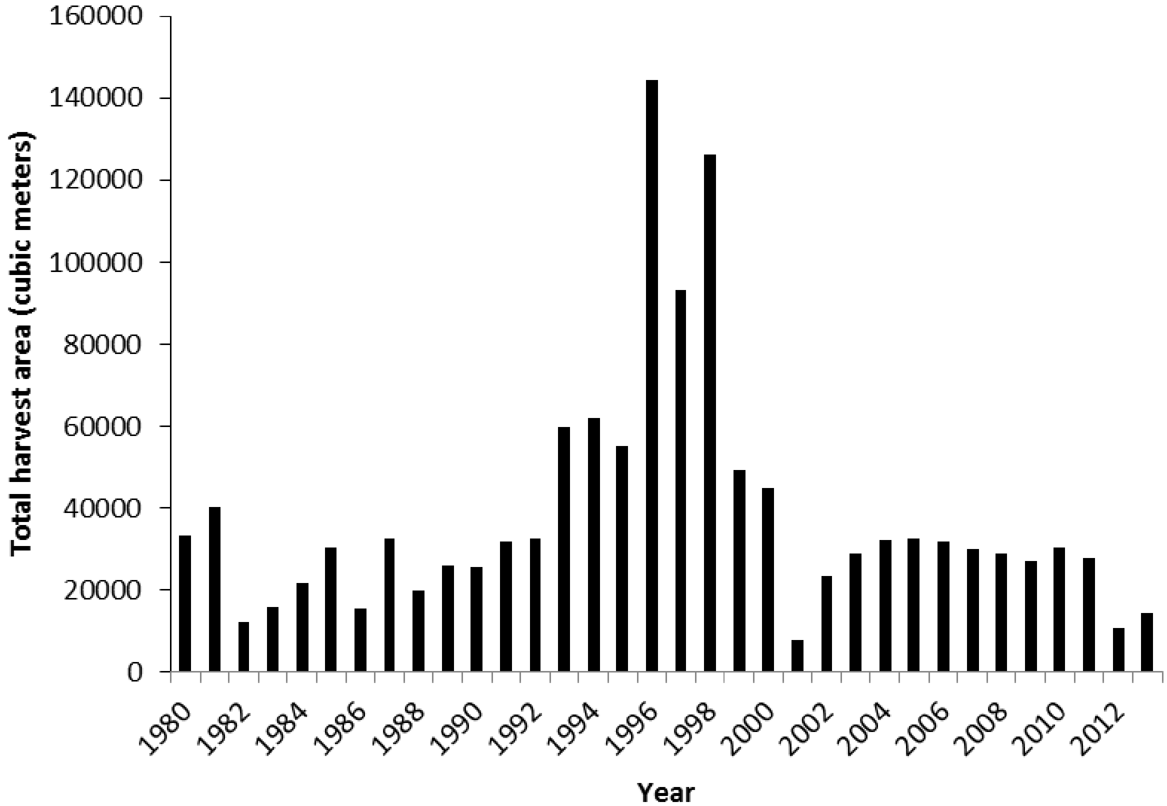

Figure 25. Historic annual timber harvest volume in the NWT. Figure reproduced from ENR (2015e).

Forest Management Agreements (FMAs) were recently signed in the Fort Providence and Fort Resolution areas (ENR2015a, b, and c) and land use permits have been issued for timber harvesting in both areas (MVLWB 2015b and c). With these now in place, timber harvesting is expected to dramatically increase in these areas(ENR2015a, b, and c). The land use permits cover five years of timber harvesting, although the FMAs themselves are for 25 years (Fig. 26, p. 81). Timber harvesting in each area will impact approximately 1,000-1,200 ha/year throughout the lifetime of the FMA (ENR 2015a, b, and c).

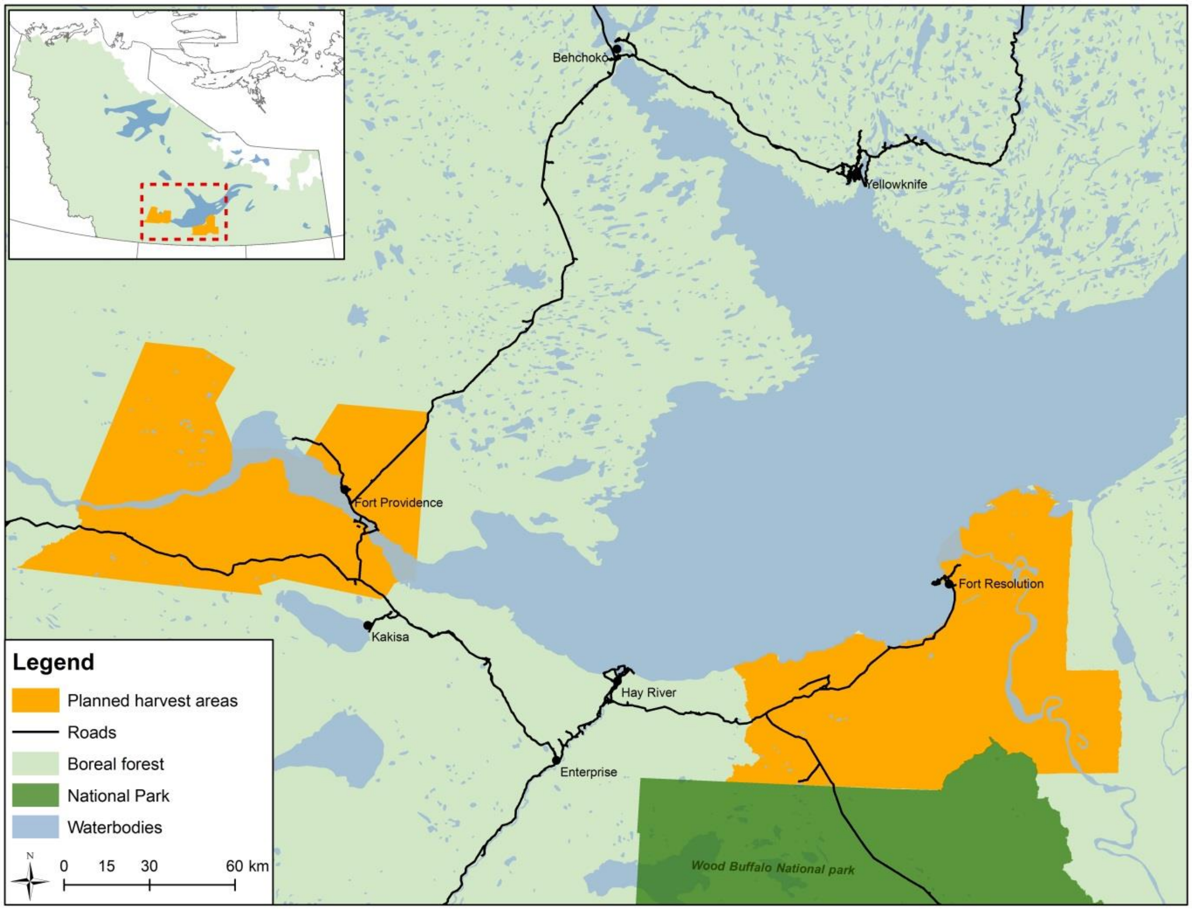

Figure 26. 25-year timber harvest areas proposed by Timberworks and Digaa Enterprises in the South Slave region, NWT. Map created by J. Reimer (AKNHP) using data obtained online from permit application shapefiles available through the Mackenzie Valley Land and Water Board (MVLWB) Public Registry (2015a; permits MV2015W0011 and MV2015W0018**.**).

Other potential threats

Intentional eradication (extermination) of an entire colony is a potential threat to bats in the NWT although it has not yet been reported in the territory; however, removal of individuals in the NWT has been reported (*see Interactions with Humans,* p.58). Elsewhere in Canada, some maternity colonies of bats in buildings are exterminated (using chemicals) because of noise, accumulation of feces, and fears about disease. The number of exterminations in Canada is unknown, but is likely in the hundreds each year. As a maternity colony may contain most of the breeding females and offspring for a large area, colony eradication can be significant to local populations (COSEWIC 2013).

As noted in *Interactions* (p. 55), common house cats prey on bats that roost in buildings (Rysgaard 1942; O'Shea *et al*. 2011; Ancillotto *et al*. 2013). Numerous cat-related bat fatalities have been reported in the NWT, and samples submitted to ENR in Fort Smith (Kelly pers. comm. 2014), but these incidences are not tracked formally and cannot be quantified. Mortality due to cats also occurs in the Yukon, with cats being known to kill juvenile little brown myotis that have recently fledged (Jung pers. comm. *in* Environment Canada 2015). Predation by cats is expected to impact bats using building roosts in or near communities, because of their proximity to cats. The impact of this threat on bat populations in the NWT is unknown but presumably small.

Mercury contamination is a potential threat to bats in the NWT but its prevalence and impact in the territory are unknown. Mercury is a naturally occurring element that is enriched by human activities and can be deposited in remote areas through long-range atmospheric transport (Fitzgerald *et al.* 1997). Bats appear to be particularly susceptible to mercury accumulation and recent studies have raised concerns about the impact of mercury on bats (Karouna-Renier *et al.* 2014; Yates *et al*. 2014; Environment Canada 2015; Little *et al.* 2015).

Changes to the boreal forest associated with climate change could affect roosting and foraging habitat, prey availability, and reproductive success (see *Habitat fragmentation and trends*, p. 71). There may be both positive and negative effects, and the ultimate impacts on bats are unknown.

Outside of the NWT, wind turbines are considered a threat to various bat species. Local, non-migratory species including *Myotis* are killed at lower rates than long-distance migrant species (e.g., 0-13% of fatalities) (Arnett *et al*. 2008). Zimmerling and Francis (2016) found that as of 2013 about 47,400 bats were killed each year by wind turbines in Canada, of which about 13% were little brown myotis. However, there are currently no large-scale wind energy developments in the NWT (Canadian Wind Energy Association 2013).

Contaminants, such as polybrominated diphenyl ethers (PBDE's), pesticides, pharmaceuticals and personal care products have been found in tissue samples from many bat species in northeastern North America, including big brown bats and little brown and northern myotis (Secord et al. 2015). Contaminants like pharmaceuticals and personal care products are likely of little concern for bats in the NWT because of the low density human population. However, contaminants like PBDE's and pesticides, that are long-ranged transported, may pose more of a threat. PBDE's have been detected in NWT resident wildlife (Larter *et al.* 2015; unpublished data).

POSITIVE INFLUENCES

Bats in the NWT are subject to fewer threats compared to many places elsewhere in North America. There is relatively little habitat loss or degradation within their range compared to southern Canada, and there is no WNS or large-scale wind energy development within their NWT range as of 2015 (see *Threats and limiting factors*, p.73). In addition, bat research and monitoring efforts have increased in the NWT over the past 5-10 years, allowing for an increased understanding of bat species in the NWT. Parks, governments, First Nations, and renewable resources boards have also been involved in creating public awareness about bats in communities, and developing strategies such as a cave management plan to mitigate potential threats.

Public education and community involvement

In the past five years, numerous community presentations, media interviews, and public education materials focused on bats and current research in the NWT have been provided throughout the territory by university researchers, local biologists, renewable resource boards, and non-profit organizations. Recently, researchers have engaged community members in a long-term bat monitoring project by involving local participants in annual emergence counts at known maternity roosts in the Fort Smith area (Kaupas pers. comm. 2015; NWT News/North 2014). Community involvement in long-term monitoring may allow a future assessment of population trends at maternity roosts in the area.

During 2011/2012, ENR engaged in an NWT public outreach program for the ‘Year of the Bat’, which was a global species awareness campaign. ENR developed and distributed a poster[7] and brochure[8] on bats in the NWT to raise awareness and encourage education about bats in NWT schools. They also developed interpretive signs at the Lady Evelyn Falls campground to inform visitors about the local bat population and the artificial maternity roosts constructed near the shower buildings (see *Positive influences - Artificial maternity roosts*, p. 83). Ecology North, a non-profit environmental organization based in Yellowknife and Hay River, and the Sahtú Renewable Resources Board (SRRB), hosted public education events, including workshops on the construction of bat houses to provide roosting habitat. Ecology North also developed a bat-focused school curriculum while the SRRB purchased bat detectors and are using the information gathered to establish baseline data for bats in their region (Environment Canada *et al*. 2016). These presentations and education materials continue to engage community members and create positive experiences between local residents and local bat populations (Kaupas pers. comm. 2015; Reimer pers. comm. 2015; Wilson pers. comm. 2015). Increasing public awareness and education of bats in the NWT will likely improve accuracy of identification and increased reporting of bat sightings in the future.

Artificial maternity roosts

During autumn 2011, two large artificial nursery bat houses were erected near the Lady Evelyn Falls campground shower building, where a colony of 100 little brown myotis was residing. This

---

[7] http://www.enr.gov.nt.ca/files/bat-nwt-poster

[8] http://www.enr.gov.nt.ca/files/bats-nwt

project was initiated to assist the campground in relocating the maternity colony out of the campground buildings. During summer 2012, a small number of bats were observed using the artificial roosts, including females with visible bands from 2011. During 2013 and 2014, increasing numbers of bats were observed using the maternity boxes. This project has naturally relocated a portion of the maternity colony out of the shower building without disturbing or harming the population.

ENR occasionally receives enquiries from the general public regarding how to build a bat house and where to place them (Wilson pers. comm. 2015), which suggests that there is some community interest in bats, and a recognition that having bats in the area can have positive implications. As noted in the previous subsection, both Ecology North and the SRRB have hosted bat house building workshops through the NWT Species at Risk Stewardship Program (Environment Canada *et al.* 2016). Through this workshop they provided materials and assistance for community members to build their own bat houses.

Recent national listings and recovery strategy

Little brown myotis, northern myotis, and the tri-coloured bat were emergency listed in 2014 as endangered under the federal *Species at Risk Act* (SARA) (November 2013; Species at Risk Public Registry 2015) as their survival is imminently threatened by WNS. Eastern populations of these three bat species have suddenly and dramatically declined owing to this disease. Only the little brown myotis and northern myotis have ranges in the NWT.

The listing of these bats means that these species are legally protected in the NWT where they are found on federal lands that are under the authority of the Minister of the Environment or the Parks Canada Agency. These legal protections on federal lands prohibit human-inflicted bodily harm (e.g., killing, capture, harassment, removal) and the damage or destruction of the residence or one or more individuals. The NWT as a jurisdiction is expected to provide effective protections on non-federal lands. Under SARA; a protection order may be put in place if individuals and residences are not effectively protected.

Following the federal listing, a national recovery strategy is being developed for these species (Environment Canada 2015) to identify actions required to address the threats to these species. It will also partially identify critical habitat and include a schedule of studies to complete the identification of critical habitat. Once the recovery strategy is posted as final, critical habitat must be protected from destruction. As for individuals and residences, critical habitat on federal lands will have legal protection and the NWT as a jurisdiction is expected to provide effective protection on non-federal lands. Activities likely to destroy critical habitat are identified in the species' recovery strategy. Examples of such activities could include research, timber harvest, mining operations, wind energy, caving tourism, and managing bats in buildings. In addition to identifying critical habitat, the national recovery strategy for little brown myotis, northern myotis, and tri-coloured bats will set strategic direction (objectives and broad strategies) to recover these species (Environment Canada 2015). One or more action plans will be developed within three years following the final posting of this recovery strategy.

Other management and action plans

Also at a national level, the Canadian Wildlife Health Cooperative has released The Canadian White-Nose Syndrome Action Plan (Canadian Wildlife Health Cooperative 2015). This document outlines the goals and action items of the Canadian WNS technical working groups that have been established to coordinate and organize Canada's response to WNS.

ENR is currently leading the development of a Cave Management Plan for hibernacula in the South Slave region of NWT (Kelly pers. comm. 2016). This management plan will facilitate stewardship and protection of these important hibernation sites in a changing environment.

Best management practice guidelines are available to mitigate human impacts on bats. Examples including performing activities during the season when bats are not present, such as harvesting timber during winter when bats are not in the area or are not using tree roosts, or 'bat-proofing' your house in autumn after reproductive colonies have left the building, and providing an alternative residence by installing a bat box in the area.

Organized working groups

The NWT currently participates in numerous coordinating bodies that are working towards bat conservation, including the Western Bat Working Group, Western Canada Bat Working Group, Northern Bat Working Group, Canadian Inter-agency WNS Committee, and Canada Wildlife Health Cooperative (Wilson pers. comm. 2015). These groups help with sharing information on bats and WNS, and coordinating bat conservation and monitoring efforts across jurisdictions.

Conservation/protected areas

The NWT range of bats includes areas currently under negotiation in lands, resources and self-government processes for the Dehcho First Nations and the Acho Dene Koe First Nation. It is possible that some protection of bat habitat, an ecological value, could be provided for through zoning and under a regional land use plan currently under development. A land use plan will describe what types of activities should occur, generally where they should take place, and terms and conditions necessary to guide land use proposals and development projects over time. Some bat habitat is already protected in the 44,807 km^2 Wood Buffalo National Park in Alberta and the NWT and the 30,050 km^2 Nahanni National Park Reserve.

Climate change

Climate plays an important role in determining food availability, timing and duration of hibernation, energy expenditure, torpor use, reproduction rates, and development rates in juvenile bats (Frick *et al.* 2010b; Sherwin *et al.* 2012). It is possible that warming temperatures may facilitate shorter hibernation periods and a longer breeding season, and therefore higher reproductive success (see *Life cycle and reproduction*, p. 51). There has also been speculation about warming temperatures increasing habitat availability for bats at the northern limit of their range (Humphries *et al.* 2002); however, changing climate patterns are complex. Whether bats will move farther north with climate change or remain restricted by other factors such as roost availability has yet to be determined.

Acknowledgements

The Species at Risk Committee thanks Jesika Reimer and Tracey Gotthardt for their work preparing the drafts of this status report. This report benefited from the many comments received during the review process and we thank all of those who contributed their views to the content and structure of this report.

The following people contributed data, reports and personal communications: Karl Cox, Sharon Irwin, Tom Jung, Laura Kaupas, Allicia Kelly, Danny Allaire, Brandon Klüg, Cori Lausen, Delanie Player, Jesika Reimer, Joanna Wilson, and Aryn Wilder.

NWT karst distribution data were provided by the NWT Protected Areas Strategy (Noni Paulette, Evelyn Gah) and Wood Buffalo National Park (Sharon Irwin). Alberta species occurrence data were provided by the Alberta Fish and Wildlife Management Information System (Lisa Wilkinson and Lonnie Bilyk). Yukon information on species distribution was provided by Tom Jung (Government of Yukon). British Columbia species occurrence data were provided by the Conservation Data Centre Mapping Service (Katrina Stipec). Species' range map shape files were provided by the IUCN Red List (Craig Hilton-Taylor) and the department of Environment and Natural Resources (Joanna Wilson and Bonnie Fournier).

Priscilla Lema (Alaska Natural Heritage Program) and Bonnie Fournier (ENR) prepared data and species' range maps.

For permission to publish photos, we thank Donald Solick, Laura Kaupas, Jesika Reimer, and ENR.

Authorities contacted

Territorial government contacts

Allicia Kelly	Manager, Wildlife Research and Monitoring, Environment and Natural Resources, Fort Smith, NT.
Joanna Wilson	Wildlife Biologist (Species at Risk), Environment and Natural Resources, Yellowknife, NT.
Karl Cox	Wildlife Technician, Environment and Natural Resources, Fort Smith, NT.

Other species experts

Aryn Wilder	Post-Doctoral Researcher, Department of Biological Sciences, Boston University, Boston, MA.
Cori Lausen	Post-Doctoral Fellow, Wildlife Conservation Society Canada, Kaslo, BC.
Karen Blejwas	Wildlife Biologist, Department of Fish and Game, Juneau, AK.
Laura Kaupas	M.Sc. Student, Department of Biological Sciences, University of Calgary, Calgary, AB.
Lisa Wilkinson	Species at Risk Biologist, Alberta Environment and Sustainable Resource Development, Calgary, AB.
Sharon Irwin	Resource Management Officer, Wood Buffalo National Park, Fort Smith, NT.

Biography of preparer

Jesika Reimer received her M.Sc. degree in Ecology, with a focus on northern bat ecology, from the University of Calgary, and is currently the assistant zoologist at the Alaska Natural Heritage Program, University of Alaska, Anchorage. She has five years of experience with bat-specific research, three of which were specific to the NWT. She has planned and executed three summers of bat research in the NWT and has authored an extensive body of research on bats in the South Slave region, including her master's thesis, numerous reports to local governments, and two peer-reviewed papers recently published in the Northwestern Naturalist (2014). Reimer has worked with local governments and ENR to perform bat species surveys and monitoring in the South Slave region from 2011 through 2013 and has been an invited speaker at both the South Slave Regional Wildlife Workshop (2011) and Dehcho Regional Wildlife Workshop (2012) to discuss bats in the NWT. Reimer was an NWT resident for 18 years and through her research has fostered connections with biologists, bat researchers currently working in the NWT, and community members throughout the NWT.

Tracey Gotthardt received her M.Sc. degree in Biology from the University of Alaska, Anchorage, and has been the program zoologist at the Alaska Natural Heritage Program for the past 15 years. She has 20 years of experience working as a conservation biologist in Alaska with an emphasis on rare and endemic fauna. She was a founding member of the Alaska Bat Monitoring Program, where she helped design and establish statewide monitoring protocols for *Myotis lucifugus* for citizen scientists. She has authored status reports for the Alaska bat species *Myotis lucifugus, M. volans, M. keenii, M. californicus* and *Lasionycteris noctivagans,* which are relevant to their statewide status, and developed models of their distribution as the coordinator for the Alaska Gap Analysis Project. She has also authored national level status assessments for the Red-throated Loon (*Gavia stellata*) and for the Buff-breasted Sandpiper (*Tryngites subruficollis*) for the U.S. Fish and Wildlife Service.

Status and ranks

Big brown bat (*Eptesicus fuscus*)

Region	Coarse filter (Ranks) To prioritize	Fine filter (Status) To provide advice	Legal listings (Status) To protect under species at risk legislation
Global	G5 – Secure (NatureServe 2014)	LC – Least concern (IUCN Red List Category 2008)	No legal tools exist.
Canada	N5 (NatureServe 2011)		
Northwest Territories	**May be at Risk (NWT General Status Ranks – NatureServe 2016)**	**Data deficient (SARC 2017)**	**To be determined**
Adjacent Jurisdictions			
United States	N5 (NatureServe 1996)		
Alberta	S4S5 (NatureServe)		N/A
British Columbia	S5 (NatureServe)		N/A
Yukon Territory	SNR – NatureServe)		N/A

Little brown myotis (*Myotis lucifugus*)

Region	Coarse filter (Ranks) To prioritize	Fine filter (Status) To provide advice	Legal listings (Status) To protect under species at risk legislation
Global	G3G4 – Vulnerable to Apparently secure (NatureServe 2014)	LC – Least concern (IUCN Red List Category 2008)	No legal tools exist.
Canada	N3 (NatureServe 2012)	Endangered (COSEWIC 2013)	Endangered (SARA 2014)
Northwest Territories	**At Risk (NWT General Status Ranks – NatureServe 2016)**	**Special concern (SARC 2017)**	**To be determined**
Adjacent Jurisdictions			
United States	N3 (NatureServe 2012)		
Alberta	S5 (NatureServe)		N/A
British Columbia	S4 (NatureServe)		N/A
Yukon Territory	S1S3 (NatureServe)		N/A

Northern myotis (Myotis septentrionalis)

Region	Coarse filter (Ranks) To prioritize	Fine filter (Status) To provide advice	Legal listings (Status) To protect under species at risk legislation
Global	G1G2 – Critically imperiled to Imperiled (NatureServe 2014);	LC – Least concern (IUCN Red List Category 2008)	No legal tools exist
Canada	N2N3 (NatureServe 2012)	Endangered (COSEWIC 2013	Endangered (SARA 2014)
Northwest Territories	**At Risk (NWT General Status Ranks – NatureServe 2016)**	**Special concern (SARC 2017)**	**To be determined**
Adjacent Jurisdictions			

United States	N1N2 (NatureServe 2014)	Threatened (2015)	
Alberta	S2S3 (NatureServe)		N/A
British Columbia	S2S4 (NatureServe)		N/A
Yukon Territory	S1S2 (NatureServe)		N/A

Long-eared myotis (*Myotis evotis*)

Region	**Coarse filter (Ranks) To prioritize**	**Fine filter (Status) To provide advice**	**Legal listings (Status) To protect under species at risk legislation**
Global	G4G5 – Apparently secure to Secure (NatureServe 2014);	LC – Least concern (IUCN Red List Category 2008)	No legal tools exist
Canada	N4N5 (NatureServe 2011)		
Northwest Territories	**May be at Risk (NWT General Status Ranks 2016)**	**Data deficient (SARC 2017)**	**To be determined**
Adjacent Jurisdictions			
United States	N4N5 (NatureServe 2014)		
Alberta	S3S4 (NatureServe)		N/A
British Columbia	S4S5 (NatureServe)		N/A
Yukon Territory	N/A		N/A

Long-legged myotis (*Myotis volans*)

Region	**Coarse filter (Ranks) To prioritize**	**Fine filter (Status) To provide advice**	**Legal listings (Status) To protect under species at risk legislation**
Global	G4G5 – Apparently secure to Secure (NatureServe 2014);	LC – Least concern (IUCN Red List Category 2008)	No legal tools exist.
Canada	N4N5 (NatureServe 2011)		
Northwest Territories	**May be at Risk (NWT General Status Ranks 2016)**	**Data deficient (SARC 2017)**	**To be determined**
Adjacent Jurisdictions			
United States	N5 (NatureServe 1996)		
Alberta	SU (NatureServe)		N/A
British Columbia	S4S5 (NatureServe)		N/A
Yukon Territory	SU (NatureServe)		N/A

Information sources

Adams, R.A. 1996. Size-specific resource use in juvenile little brown bats, *Myotis lucifugus* (Chiroptera: Vespertilionidae): is there an ontogenetic shift? Canadian Journal of Zoology 74:1204-1210.

Adams, R.A. 1997. Onset of volancy and foraging patterns of juvenile little brown bats, *Myotis lucifugus*. Journal of Mammalogy 78:239-246.

Adams, R.A. 2003. Bats of the Rocky Mountain West. University Press of Colorado, Boulder, CO. 289 pp.

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: 179-198.

Agosta, S.J., D. Morton, B.D. Marsh, and K.M. Kuhn. 2005. Nightly, seasonal, and yearly patterns of bat activity at night roosts in the Central Appalachians. Journal of Mammalogy 86:1210-1219.

Alberta Environment and Sustainable Resource Development (AESRD). 2015. Species Report: Long-eared bat (*Myotis evotis*). Website: http://esrd.alberta.ca/fish-wildlife/wild-species/mammals/bats/long-eared-bat.aspx [Accessed February 2015].

Allaire, D. pers. comm. 2016. Comments on draft Species Status Report for Big Brown Bat, Little Brown Myotis, Northern Myotis, Long-eared Myotis, and Long-legged Myotis in the NWT. Wildlife Technician II, Dehcho Region, Environment and Natural Resources, Government of the Northwest Territories, Fort Simpson, NT.

Ancillotto, L., M.T. Serangeli, and D. Russo. Curiosity killed the bat: domestic cats as bat predators. Mammalian Biology (2013): in press.

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

Arlettaz, R., P. Christe, A. Lugon, N. Perrin, and P. Vogel. 2001. Food availability dictates the timing of parturition in insectivorous mouse-eared bats. Oikos 95: 105-111.

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

Arnold, B.D. 2007. Population structure and sex-biased dispersal in the forest dwelling vespertilionid bat, *Myotis septentrionalis*. American Midland Naturalist 157:374-384.

Arroyo-Cabrales, J. and S.T. Alvarez-Castaneda. 2008a. Myotis evotis. The IUCN Red List of

Threatened Species. Website: www.iucnredlist.org [Accessed 8 August 2016].

Arroyo-Cabrales, J. and S.T. Álvarez-Castañeda. 2008b. *Myotis lucifugus*. The IUCN Red List of Threatened Species. Version 2014.3. Website: www.iucnredlist.org [Accessed 1 March 2015].

Arroyo-Cabrales, J. and S.T. Álvarez-Castañeda. 2008c. *Myotis septentrionalis*. The IUCN Red List of Threatened Species. Version 2014.3. Website: www.iucnredlist.org [Accessed 1 March 2015].

Arroyo-Cabrales, J. and S.T. Álvarez-Castañeda. 2008d. *Myotis volans*. The IUCN Red List of Threatened Species. Version 2014.3. Website: www.iucnredlist.org [Accessed 1 March 2015].

Audet, D. and R.B. Fenton. 1988. Heterothermy and the use of torpor by the bat *Eptesicus fuscus* (Chiroptera: Vespertilionidae): A field study. Physiological Zoology 61:197-204.

Baker, M.D. and M.J. Lacki. 2006. Day-roosting habitat of female long-legged myotis in Ponderosa pine forests. Journal of Wildlife Management 70:207-215.

Baker, R.H. and C.J. Phillips. 1965. Mammals from El Nevado de Colima, Mexico. Journal of Mammalogy 46:691-693.

Barbour, R.W. and W.H. Davis. 1969. Bats of America. University Press of Kentucky, Lexington, KY. 312 pp.

Barclay, R. and M. Brigham. 1996. Bats and Forests Symposium, October 19-21, 1995, Victoria, BC. Paper 23/1996, British Columbia Ministry of Forests, Victoria, BC. 292 pp.

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

Barclay, R.M.R. and L.D. Harder. 2003. Life histories of bats: Life in the slow lane. Pp. 209-246. *in* T.H. Kunz and M.B. Fenton (eds.). Bat Ecology. University of Chicago Press, Chicago, IL.

Barclay, R.M.R., J. Ulmer, C.J.A. MacKenzie, M.S. Thompson, L. Olson, J. McCool, E. Cropley, and G. Poll. 2004. Variation in the reproductive rate of bats. Canadian Journal of Zoology 82: 688-693.

Beer, J.R. 1955. Survival and movements of banded big brown bats. Journal of Mammalogy 36:242-248.

Beer, J.R. and A.G. Richards. 1956. Hibernation of the big brown bat. Journal of Mammalogy 37:31-41.

Bell, G.P. 1980. Habitat use and response to patches of prey by desert insectivorous bats. Canadian Journal of Zoology 58:1876–1883.

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

Blehert, D.S., A.C. Hicks, M. Behr, C.U. Meteyer, B.M. Berlowski-Zier, E.L. Buckles, J.T.H. Coleman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2008. Bat white-nose syndrome: an emerging fungal pathogen? Science 323:227-227.

Blejwas, K. and M. Kohan pers. comm. 2014. Personal conversations. August 2014. Regional Wildlife Biologist and Wildlife Technician, Southeast Alaska (Region I),Wildlife Diversity Program, Alaska Department of Fish and Game, Juneau, AK.

Blejwas, K., M. Kohan, L. Beard, and G. Pendelton. 2015. Little brown bats in Southeast Alaska hibernate in holes: implications for the spread of white-nose syndrome [Abstract]. North American Symposium of Bat Research, Monterey, CA, October 28 - 31, 2015.

Bogdanowicz, W., K. Piksa, and A. Tereba. 2012. Hybridization hotspots at bat swarming sites. PLoS ONE 7(12): e53334. doi: 10.1371/journal.pone.0053334.

Bohning, R.A., D. Campbell and J. Grave. 1997. Forests of the Northwest Territories. [Pamphlet]. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. 16 pp. Website: http://cfs.nrcan.gc.ca/bookstore_pdfs/20057.pdf [Accessed November 2015]

Boyles, J.G. and D.P. Aubrey. 2006. Managing forests with prescribed fire: Implications for a cavity-dwelling bat species. Forest Ecology and Management 222:108-115.

Boyles, J.G. and C.K.R. 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 8:92–98.

Brack, V. and J.O. Whitaker, Jr. 2001. Foods of the northern myotis, *Myotis septentrionalis*, from Missouri and Indiana, with notes on foraging. Acta Chiropterologica 3:203-210.

Bradbury, S.M., S. Morris, and S. McNalley. 1997. Bat survey of the Liard River watershed in British Columbia: the lower Liard River and Highway 77 area. Wildlife Branch, Lands and Parks, British Columbia Ministry of Environment, Victoria, BC. 29 pp.

Brandt, J.P. 2009. The extent of the North American boreal zone. Environmental Reviews 17:101-161.

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

Brigham, R.M. 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 64:1128-1133.

Brigham, R.M. and M.B. Fenton. 1991. Convergence in foraging strategies by two morphologically and phylogenetically distinct nocturnal aerial insectivores. Journal of Zoology, London 223: 475-489.

Brigham, R.M. and M.B. Saunders. 1990. The diet of big brown bats (*Eptesicus fuscus*) in relation to insect availability on southern Alberta, Canada. Northwest Science 64:7-10.

British Columbia Ministry of Environment. 2008. Conservation Data Centre mapping service. [data set]. Occurrence records for *Eptesicus fuscus*, *Myotis lucifugus*, *Myotis septentrionalis*, *Myotis evotis* and *Myotis volans*.

Brittingham, M.C. and L.M. Williams. 2000. Bat boxes as alternative roosts for displaced bat maternity colonies. Wildlife Society Bulletin 28:197-207.

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 70:1174-1184.

Broders, H., G. Forbes, S. Woodley, and I. Thompson. 2005. Range extent and stand selection for roosting and foraging in forest dwelling *Myotis septentrionalis* and *M. lucifugus* in the Greater Fundy Ecosystem, New Brunswick. Journal of Wildlife Management 70(5): 1174-1184.

Broders, H., G. Quinn, and G. Forbes. 2003. Species status, and the spatial and temporal patterns of activity of bats in southwest Nova Scotia, Canada. Northeastern Naturalist 10: 383-398.

Buchler, E.R. 1976. Prey selection by *Myotis lucifugus* (Chiroptera: Vespertilionidae). The American Naturalist 110:619-628.

Burnett, C.D. and T.H. Kunz. 1982. Growth rates and age estimation in *Eptesicus fuscus* and comparison with *Myotis lucifugus*. Journal of Mammalogy 63:33-41.

Burns, L.E., T.R. Frasier, and H.G. Broders. 2014. Genetic connectivity among swarming sites in the wide ranging and recently declining little brown bat (*Myotis lucifugus*). Ecology and Evolution 4:4130–4149.

Buseck, R.S. and D.A. Keinath. 2004. Species assessment for western long-eared myotis (*Myotis evotis*) in Wyoming. Prepared for United States Department of the Interior, Bureau of Land Management, Cheyenne, WY. 76 pp.

Caceres, M.C. and R.M.R. Barclay. 2000. *Myotis septentrionalis*. Mammalian Species 634:1-4.

Cagle, F.R. and L. Cockrum. 1943. Notes on a summer colony of *Myotis lucifugus*. Journal of Mammalogy 24: 474-492.

Canadian Wildlife Health Cooperative. 2015. A national plan to manage white nose syndrome in bats in Canada. Revised February 2015. Website: www.cwhc-rcsf.ca/docs/BatWhiteNoseSyndrome-NationalPlan.pdf [Accessed November 2015].

Canadian Wildlife Health Cooperative (CWHC), 2016. Surveillance Data – White Nose Syndrome for 2016, Summary by Province. Website: http://www.cwhc-rcsf.ca/surveillance_data_wns.php [Accessed October 2016].

Canadian Wind Energy Association. 2013. Case study: Diavik wind farm: wind energy helps reduce carbon footprint. [Electronic pamphlet] Website: http://canwea.ca/wp-content/uploads/2013/12/canwea-casestudy-DiavikMine-e-web2.pdf [Accessed November 2015]

Carter, T.C. and G.A. Feldhamer. 2005. Roost tree use by maternity colonies of Indiana bats and northern long-eared bats in southern Illinois. Forest Ecology and Management 219:259-268.

Center for Geomatics. 2015. Datasets for fire history (1965-2015) throughout the NWT. Center of Geomatics, Government of the Northwest Territories, Yellowknife, NT. Website: http://www.geomatics.gov.nt.ca/ [Accessed December 2015].

Chaturvedi, V., T. Victor, J. Okoniewski, X. Li, E. Ferri, C. Gunsch, P. Ren, and S. Chaturvedi. 2012. Identifying the natural habitat of Geomyces destructans, the etiological agent of bat geomycosis. Abstract. 5th Annual White-nose Syndrome Symposium, June 4-7, 2012, Madison, Wisconsin.

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

Cockrum, E.L. 1956. Homing, movements, and longevity of bats. Journal of Mammalogy 37:48-57.

Coleman, J.T.H. and J.D. Reichard. 2014. Bat white-nose syndrome in 2014: a brief assessment seven years after the discovery of a virulent fungal pathogen in North America. Outlooks on Pest Management, December 2014:374-377.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2013. COSEWIC assessment and status report on the little brown myotis *Myotis lucifugus*, northern myotis *Myotis septentrionalis* and tri-colored bat *Perimyotis subflavus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. xxiv + 93 pp.

Constatine, D.G. 1979. An updated list of rabies-infected bats in North America. Journal of Wildlife Diseases 15:347-349.

Cooper, K. pers. comm. 2016. Email correspondence to J. Wilson. October 2016. Species at Risk Biologist, Gwich'in Renewable Resources Board, Inuvik, NT.

Cornelison, C.T., M.K. Keel, K.T. Gabriel, C.K. Barlament, T.A. Tucker, G.E. Pierce, and S.A. Crow. 2014a. A preliminary report on the contact-independent antagonism of *Pseudogymnoascus destructans* by *Rhodococcus rhodochrous* strain DAP96253. BMC Microbiology, published online: DOI 10.1186/s12866-014-0246-y.

Cornelison, C.T., K.T. Gabriel, C. Barlament, and S.A. Crow Jr. 2014b. Inhibition of *Pseudogymnoascus desctructans* growth from conidia and mycelial extension by bacterially produced volatile organic compounds. Mycopathologia 177(1-2): 1-10.

Cox, K. pers. comm. 2015. Phone and email correspondence to J. Reimer. March 2015. Wildlife Technician, South Slave Region, Environment and Natural Resources, Government of the Northwest Territories, Fort Smith, NT.

Crampton, L. and R. Barclay. 1996. Habitat selection by bats in fragmented and unfragmented aspen mixedwood stands of different ages. Pp. 238-259 *in* M. Brigham and R. Barclay (Eds.). Bats and Forests Symposium, October 19-21, 1995, Victoria, BC. Paper 23/1996. British Columbia Ministry of Forests, Victoria, BC. 292 pp.

Cross, S.P. 1977. A survey of the bats of Oregon caves national monument [Report]. National Park Service, Contract CX-9000-6-0061. 40 pp.

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

Cryan, P.M., C.U. Meteyer, J.G. Boyles, and D.S. Blehert. 2010. Wing pathology of white-nose syndrome in bats suggests life-threatening disruption of physiology. BMC Biology 8:135.

Czenze, Z.J. and H.G. Broders. 2011. Ectoparasite community structure of two bats (*Myotis lucifugus* and *M. septentrionalis*) from the maritimes of Canada. Journal of Parasitology Research, doi: 10.11.1155/2011/341535.

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 27:60-63.

Davis, W.H. and R.W. Barbour. 1970. Life history data on some southwestern *Myotis*. The Southwestern Naturalist: 261-263.

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

Davis, W.H. and O.B. Reite. 1967. Responses of bats from temperate regions to changes in ambient temperature. Biological Bulletin 132:320-328.

Deneron, D. pers. comm. 2016. Conversation with N. Larter. October 2016. Resident, Trout Lake, NT.

Dick, C.W., M.R. Gannon, W.E. Little, and M.J. Patrick. 2003. Ectoparasite associations of bats from Central Pennsylvania. Journal of Medical Entomology 40:813-819.

Dobony C.A., A.C. Hicks, K.E. Langwig, R.I. von Linden, J.C. Okoniewski, and R.E. Rainbolt. 2011. Little brown myotis persist despite exposure to white-nose syndrome. Journal of Fish and Wildlife Management 2:190–195.

Dyer, S.J., J.P O'Neill, S.M. Wasel, and S. Boutin. 2002. Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. Canadian

Journal of Zoology 80: 839–845.

Dzal, Y.A. and R.M. Brigham. 2012. The trade-off between torpor use and reproduction in little brown bats (*Myotis lucifugus*). Journal of Comparative Physiology B 183:279-288.

Dzal, Y., L.P. McGuire, N. Veselka, and M.B. Fenton. 2011. Going, going, gone: the impact of white-nose syndrome on the summer activity of the little brown bat (*Myotis lucifugus*). Biology letters 7:392-394.

Ecosystem Classification Group. 2007 (rev. 2009). Ecological regions of the Northwest Territories – Taiga Plains. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT, Canada. viii + 173 pp. + folded insert map.

Ecosystem Classification Group. 2008. Ecological regions of the Northwest Territories – Taiga Shield. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT, Canada. viii + 146 pp. + insert map.

Ecosystem Classification Group 2010. Ecological regions of the Northwest Territories – Cordillera. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. X + 170 p. + insert map.

Ecosystem Classification Group. 2012. Ecological regions of the Northwest Territories – Southern Arctic. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT, Canada. x + 170 pp. + insert map.

Elkin, B. pers. comm. 2015. Email correspondence to J. Reimer. March 2015. Disease/Contaminants Specialist, Wildlife Division, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT.

Environment Canada. 2015. Recovery strategy for little brown myotis (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), and tri-colored bat (*Perimyotis subflavus*) in Canada [Draft]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. viii + 111 pp.

Environment Canada, Fisheries and Oceans Canada, and Government of the Northwest Territories. 2016. Species at risk in the NWT: 2016. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 100 pp.

Environment and Natural Resources (ENR). 2012. Northwest Territories Biomass Energy Strategy 2012-2015. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 24 pp.

Environment and Natural Resources (ENR). 2014a. 2014 NWT fire season review report. Website: http://www.enr.gov.nt.ca/sites/default/files/web_pdf_fmd_2014_fire_season_review_report_4_may_2015.pdf [Accessed August 2016].

Environment and Natural Resources (ENR). 2014b. Bat species range map shape files (*Myotis lucifugus*, *Myotis septentrionalis*). Available from: Wildlife Biologist (Species at Risk), Environment and Natural Resources, Government of the Northwest Territories, PO Box 1320, Yellowknife NT, X1A 2L9, SARA@gov.nt.ca.

Environment and Natural Resources (ENR) 2014c. NWT bat monitoring, update 2014 [Poster]. Available from: Joanna Wilson, Environment and Natural Resources, Government of the Northwest Territories, joanna_wilson@gov.nt.ca.

ENR 2015a. Digaa Enterprises limited forest management agreement, timber harvest planning area: 25 year strategic plan (2015-2040) - Part 1. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. Website: http://www.mvlwb.ca/Boards/mv/Registry/2015/MV2015W0018/MV2015W0018%20-%20Digaa%20Enterprises%20-%20Ft%20Providence%20FMA%2025%20Year%20Mngmt%20Plan%20-%20Sept30-15.pdf [Accessed August 2016].

ENR 2015b. Submission letter in support for Class A Land Use Permit: Timberworks Inc. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. Website: http://www.mvlwb.ca/Boards/mv/Registry/2015/MV2015W0011/MV2015W0011%20-%20Timberworks%20-%20Forest%20MGMT%20Agreement%20-%2025%20Year%20Strategic%20Harvest%20Plan%20-%20Part%201%20-%20ENR%20-%20Jul8-15.pdf [Accessed August 2016].

ENR 2015c. Digaa Enterprises limited forest management agreement, timber harvest planning area: 25 year strategic plan (2015-2040) - Part 2. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. Website: http://www.mvlwb.ca/Boards/mv/Registry/2015/MV2015W0011/MV2015W0011%20-%20Timberworks%20-%20Forrest%20MGMT%20Agreement%20-%2025%20Year%20Strategic%20Harvest%20Plan%20-%20Part%202-%20Jul8-15.pdf [Accessed August 2016].

Environment and Natural Resources (ENR). 2015d. NWT current wildfire situation report. Website: http://www.enr.gov.nt.ca/node/20 [Accessed August 2016].

Environment and Natural Resources (ENR). 2015e. NWT State of the Environment Report. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. Website: http://www.enr.gov.nt.ca/state-environment [Accessed November 2015].

Environment and Natural Resources (ENR), unpubl. data. 2015. Acoustic monitoring records from SSR-1 and SSR-2 bat hibernacula, South Slave region, NWT. Environment and Natural Resources, Government of the Northwest Territories, Fort Smith, NT.

Environment and Natural Resources (ENR), unpubl. data. 2016a. Acoustic monitoring records from bat detectors in the South Slave, Dehcho, Sahtú and North Slave regions, NWT. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT.

Environment and Natural Resources, unpubl. data. 2016b. NWT Wildlife Management Information System. Project 250 – NWT – bat observations 1907 to present. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT.

Ethier, K. and L. Fahrig. 2011. Positive effects for forest fragmentation, independent of forest amount, on bat abundance in eastern Ontario, Canada. Landscape Ecology 26(6): 865-876.

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 174:651-660.

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

Faure, P.A., J.H. Fullard, and R.M.R. Barclay. 1990. The response of tympanate moths to the echolocation calls of a substrate gleaning bat, *Myotis evotis*. Journal of Comparative Physiology A 166: 843-849.

Feldhamer, G.A., T.C. Carter, and S.K. Carroll. 2001. Timing of pregnancy, lactation, and female foraging activity in three species of bats in southern Illinois. Canadian Field-Naturalist 115: 420-424.

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

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

Fenton, M.B. and G.P. Bell. 1981. Recognition of species of insectivorous bats by their echolocation calls. Journal of Mammalogy 62:233-243.

Fenton, M.B., I.L. Rautenbach, S.E. Smith, C.M. Swanepoel, J. Grosell, and J. van Jaarsveld. 1994. Raptors and bats: threats and opportunities. Animal Behaviour 48:9-18.

Fenton, M.B., S.B. Peck, and R.G. Syme. 1973. A biological survey of caves in and around Nahanni National Park, NWT, Canada. Canadian Caver 5: 35-42.

Fisher, J.T. and L. Wilkinson. 2005. The response of mammals to forest fire and timber harvest in the North American boreal forest. Mammal Review 35:51-81.

Fisheries & Wildlife Management Information System (FWMIS). 2015. Alberta bat occurrence data records [spatial data - excel spreadsheet]. Alberta Environment and Sustainable Resource Development, Government of Alberta, Edmonton, AB.

Fishman, M. 2015. Bats at the beach: northern long-eared bats are alive and well in northeastern coastal communities [abstract]. North American Symposium for Bat Research, Monterey, CA, October 28 - 31, 2015.

Fitzgerald, W.F., D.R. Engstrom, R.P. Mason, and E.A. Nater. 1997. The case for atmospheric mercury contamination in remote areas: a critical review. American Chemical Society, published on web on 01/01/1998.

Flory, A.R., S. Kumar, T.J. Stohlgren, and P.M. Cryan. 2012. Environmental conditions associated with bat white-nose syndrome mortality in the North-Eastern United States. Journal of Applied Ecology 49:680–689.

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 25:223-231.

Ford, D. 2008. Survey of karst landforms in the Sahtú region. NWT Protected Areas Strategy, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 231 pp. Website: http://www.nwtpas.ca/science-karst.asp [Accessed December 2015].

Ford, D. 2009. Mapping known and potential karst areas in the Northwest Territories, Canada. Prepared for Environment and Natural Resources, Government of the Northwest Territories. McMaster University, Hamilton, ON. 65 pp.

Foster, R.W. and A. Kurta. 1999. Roosting ecology of the northern bat (*Myotis septentrionalis*) and comparisons with the endangered Indiana bat (*Myotis sodalis*). Journal of Mammalogy 80:659-672.

Francl, K.E., W.M. Ford, D.W. Sparks, and V. Brack, Jr. 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 3:33-42.

Frank, C.L., A. Michalski, A.A. McDonough, M. Rahimian, R.J. Rudd, and C. Herzog. 2014. The resistance of a North American bat species (*Eptesicus fuscus*) to white-nose syndrome (WNS). PloS one 9: e113958.

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. 2010a. An emerging disease causes regional population collapse of a common North American bat species. Science 329:679-682.

Frick, W.F., D.S. Reynolds, and T.H. Kunz. 2010b. Influence of climate and reproductive timing on demography of little brown myotis *Myotis lucifugus*. Journal of Animal Ecology 79:128-136.

Gabriel, K. 2015. WNS-treated bats released into wild. CrowLab, Georgia State University. Website: http://sites.gsu.edu/crowlab/2015/05/21/wns-treated-bats-released-into-wild/ [Accessed August 2016].

Garroway, C.J. and H.G. Broders. 2008. Day roost characteristics of northern long-eared bats (*Myotis septentrionalis*) in relation to female reproductive status. Ecoscience 15:89-93.

Gifford, C.E. and D.R. Griffin. 1960. Notes on homing and migratory behavior of bats. Ecology 41:378-381

Girard, K., H. Hitchcock, G. Edsall, and R. MacCready. 1965. Rabies in bats in southern New England. New England Journal of Medicine 272: 75-80.

Government of Yukon. 2011. Yukon Bats, brochure. Website: maps/documents/yukonbats_brochure.pdf [accessed September 2016].

Grieneisen, L. 2011. Hibernacula microclimate and white-nose syndrome susceptibility in the little brown myotis (Myotis lucifugus). M.Sc. Thesis. Bucknell University, Lewisburg, PA.

Griffin, D.R. 1940. Notes on the life histories of New England cave bats. Journal of Mammalogy 21:181-187.

Griffin, D.R. 1945. Travels of banded cave bats. Journal of Mammalogy 26:15-23.

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

Grindal, S.D., C.I. Stefan, and C. Godwin-Sheppard. 2011. Diversity, distribution, and relative abundance of bats in the oil sands regions of Northeastern Alberta. Northwestern Naturalist 92: 211-220.

Grindal, S. and M. Brigham. 1999. Impacts of forest harvesting on habitat use by foraging insectivorous bats at different spatial scales. Ecoscience 6: 25-34.

Gwich'in Language Centre and Gwich'in Social and Cultural Institute (GSCI). 2005. Teetl'it ts'at Gwichyah Gwich'in Ginjik Gwi'dinehtl'ee': Gwich'in Language Dictionary (Fort McPherson and Tsiigehtchic dialects). 5th Ed. Gwich'in Language Centre and Gwich'in Social and Cultural Institute, Teetl'it Zheh and Tsiigehtchic, NT. 276 pp.

Hamilton, I.M. and R.M.R. Barclay. 1998. Diet of juvenile, yearling, and adult big brown bats (*Eptesicus fuscus*) in Southeastern Alberta. Journal of Mammalogy 79:764-771.

Hayman, D.T.S., J.R.C. Pulliam, J.C. Marshall, P.M. Cryan, and C.T. Webb. 2016. Environment, host, and fungal traits predict continental-scale white-nose syndrome in bats. Sci, Adv. 2016, 2: e1500831. Website: http://advances.sciencemag.org/content/advances/2/1/e1500831.full.pdf [Accessed August 2016].

Henderson, L.E. and H.G. Broders. 2008. Movements and resource selection of the northern long-eared myotis (*Myotis septentrionalis*) in a forest - agriculture landscape. Journal of Mammalogy 89:952-963.

Henderson, L., L. Farrow, and H. Broders. 2008. Intra-specific effects of forest loss on the distribution of the forest-dependent northern long-eared bat (*Myotis septentrionalis*). Biological Conservation 141: 1819-1828.

Hendricks, P. 2012.Winter records of bats in Montana. Northwestern Naturalist 93:154-162.

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

Hogburg, 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. The American Midland Naturalist 148:282-288.

Holloway, G.L. 1998. The ecology of prairie-dwelling bats in Southeastern Alberta. M.Sc. Thesis, University of Calgary, Calgary, AB. 100 pp.

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

Holroyd, S.L. 1993. Influences of some extrinsic and intrinsic factors on reproduction by big brown bats (*Eptesicus fuscus*) in southeastern Alberta. M.Sc. thesis, University of Calgary, Calgary, AB.

Hoyt, J.R., K.E. Langwig, J. Okoniewski, W.F. Frick, W.B. Stone, and A.M. Kilpatrick. 2015. Long-term persistence of *Pseudogymnoascus destructans*, the causative agent of white-note syndrome, in the absence of bats. Ecohealth 12: 330-333.

Humes, M.L., J.P. Hayes, and M.W. Collopy. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. Journal of Wildlife Management 63:553–561.

Humphrey, S. and J. Cope. 1976. Population ecology of the little brown bat, *Myotis lucifugus*, in Indiana and north-central Kentucky. American Society Mammalogists Special Publication 4:1-81.

Humphries, M.M., D.W. Thomas, and J.R. Speakman. 2002. Climate-mediated energetic constraints on the distribution of hibernating mammals. Nature (London) 418:313–316.

International Union for the Conservation of Nature (IUCN). 2012. IUCN Red List of Threatened Species. Range maps for *E. fuscus, Myotis lucifugus, M. evotis, M. septentrionalis* and *M. volans* [spatial data – shape files] Version 2012.1. Website: http://www.iucnredlist.org [Accessed February 2015].

International Union for the Conservation of Nature (IUCN). 2014. Guidelines for using the IUCN Red List categories and criteria. Version 11. Prepared by the Standards and Petitions Subcommittee. Website: http://www.amphibians.org/wp-content/uploads/2014/02/RedListGuidelines-v11.pdf [Accessed August 2016].

Johnson, J.B., J.W. Edwards, and W.M. Ford. 2011. Nocturnal activity patterns of northern myotis (*Myotis septentrionalis*) during the maternity season in West Virginia (USA). Acta

Chiropterologica 13:391-397.

Johnson, J.B., J.W. Edwards, W.M. Ford, and J.E. Gates. 2009. Roost tree selection by northern myotis (*Myotis septentionalis*) maternity colonies following prescribed fire in a central Appalachian Mountains hardwood forest. Forest Ecology and Management 258:233-242.

Johnson, J.B., W.M. Ford, and J.W. Edwards. 2012. Roost networks of northern myotis (*Myotis septentrionalis*) in a managed landscape. Forest Ecology and Management 266:223-231.

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

Jones, J.K., Jr., R.S. Hoffman, D.W. Rice, C. Jones, R.J. Baker, and M.D. Engstrom. 1992. Revised checklist of North American mammals north of Mexico, 1991. Occasional Papers, The Museum, Texas Tech University 146:1-23.

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

Jung, T.S. 2013. Estimating little brown bat (*Myotis lucifugus*) colony size in southern Yukon: a mark-recapture approach. Yukon Fish and Wildlife Branch Report TR-13-13. Whitehorse, Yukon, Canada.

Jung, T.S., K.M. Blejwas, C.L. Lausen, J.M. Wilson, and E. Olson. 2014. Concluding remarks: what do we need to know about bats in northwestern North America? Northwestern Naturalist, 95(3): 318-330.

Karouna-Renier, N.K., C. White, C.R. Perkins, J.J. Schmerfeld, and D. Yates. 2014. Assessment of mitochondrial DNA damage in little brown bats (*Myotis lucifugus*) collected near a mercury-contaminated river. Ecotoxicology 23(8): 1419-1429.

Kaupas, L. and R.M.R. Barclay. 2014. Resource partitioning in sympatric *Myotis lucifugus* and *Myotis septentrionalis* in a northern environment [abstract]. North American Symposium for Bat Research, Annual Meeting.

Kaupas, L. and R.M.R. Barclay. in prep. Resource partitioning in sympatric *Myotis lucifugus* and *Myotis septentrionalis* in a northern environment. University of Calgary, Calgary, AB.

Kaupas, L. pers. comm. 2015. Phone and email correspondence to J. Reimer. January – March 2015. M.Sc. Candidate, University of Calgary, Department of Biology, Calgary, AB.

Kaupas, L. pers. comm. 2016. Comments on draft Species Status Report for Big Brown Bats, Little Brown Myotis, Northern Myotis, Long-eared Myotis, and Long-legged Myotis in the NWT. M.Sc. Candidate, University of Calgary, Department of Biology, Calgary, AB.

Kaupas, L. 2015. Investigation of northern adaptations in tree-roosting bats in the South Slave [Research Summary Report]. Associated with research permit number WL500247. Wildlife

Division, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT.

Kaupas, L. and R. Barclay. 2015. Investigation of northern adaptations in tree-roosting bats in the South Slave Region (Research Summary Report]. Associated with research permit number WL500329. Wildlife Division, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT.

Keen, R. and H.B. Hitchcock. 1980. Survival and longevity of the little brown bat (*Myotis lucifugus*) in southeastern Ontario. Journal of Mammalogy 61: 1-7.

Kelly, A. and K. Cox. 2015. Bat research and monitoring in the South Slave, 17 March 2014 – 17 March 2015. Associated with Wildlife Research Permit WL500225. Environment and Natural Resources, Government of the Northwest Territories, Fort Smith, NT.

Kelly, A. pers. comm. 2014. Phone and email correspondence to J. Reimer. October 2014. Regional Biologist, South Slave Region, Environment and Natural Resources, Government of the Northwest Territories, Fort Smith, NT.

Kelly, A. pers. comm. 2016. Comments on draft Species Status Report for Big Brown Bat, Little Brown Myotis, Northern Myotis, Long-eared Myotis, and Long-legged Myotis in the NWT. Manager, Wildlife Research and Monitoring, South Slave Region, Environment and Natural Resources, Government of the Northwest Territories, Fort Smith, NT.

Kelly, A. unpubl. data. 2013. Temperature and 100% relative humidity readings for the South Slave Hibernaculum (November through July 2013). Environment and Natural Resources, Government of the Northwest Territories, Fort Smith, NT.

Kilpatrick, M. 2013. Transmission of *Geomyces destructans* between bats and the environment. International Bat Research Conference, San Jose, Costa Rica, 11-15 August.

Klüg, B. pers. comm. 2015. In-person conversation with J. Reimer at the National Symposium for Bat Research, Monterey, CA. October 2015. PhD candidate, University of Regina, Regina, SK.

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

Kunz, T.H. and L.F. Lumsden. 2003. Ecology of cavity and foliage roosting bats. Pp. 49-60 *In* Bat Ecology, T.H. Kunz and M.B. Fenton (eds). The University of Chicago Press, Chicago, IL.

Kunz, T.H. and J.D. Reichard. 2010. Status review of the little brown myotis (*Myotis lucifugus*) and determination that immediate listing under the *Endangered Species Act* is scientifically and legally warranted. Report in collaboration with: Friends of Blackwater Canyon, Wildlife Advocacy Project, Bat Conservation International, Center for Biological Diversity, and Meyer Glitzenstein & Crystal.

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

Kurta, A., G.P. Bell, K.A. Nagy, and T.H. Kunz. 1989. Energetics of pregnancy and lactation in free-ranging little brown bats (*Myotis lucifugus*). Physiological Zoology 62:804-818.

Kurta, A., T.H. Kunz, and K.A. Nagy. 1990. Energetics and water flux of free-ranging big brown bats (*Eptesicus fuscus*) during pregnancy and lactation. Journal of Mammalogy 71: 59-65

Lacki, M.J., D.R. Cox, L.E. Dodd, and M.B. Dickinson. 2009. Response of northern bats (*Myotis septentrionalis*) to prescribed fires in eastern Kentucky forests. Journal of Mammalogy 90:1165-1175.

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 15:1050-1057.

Langwig K.E., W.F. Frick, R. Reynolds, K.L. Parise, K.P. Drees, J.R. Hoyt, T.L. Cheng, T.H. Kunz, J.T. Foster, and A.M. Kilpatrick. 2015. Host and pathogen ecology drive the seasonal dynamics of a fungal disease, white-nose syndrome. Proceedings of the Royal Society: B 282: 20142335.

Larter, N.C., C.R. Macdonld, D.Muir, B.T. Elkin and X. Wang. 2015. Multi-elements, radionuclides and persistent organics in tissues of mountain goats in Northwest Territories. Biennial Symposium for the Northern Wild Sheep and Goat Council 19: 98-107; 2014.

Lausen, C.L. 2005. First record of hosts for tick *Carios kelleyi* (Acari: Ixodida: Argasidae) in Canada and Montana. Journal of Medical Entomology 42: 497-501.

Lausen, C.L. 2006. Bat survey of Nahanni National Park Reserve and surrounding areas, Northwest Territories [Report]. Prepared for Parks Canada, Nahanni National Park Reserve, Fort Simpson, NT and Canadian Parks and Wilderness Society, Yellowknife, NT. Kaslo, BC. vi + 39 pp.

Lausen, C.L. 2011. Late summer survey of bat hibernacula and bat diversity in South Slave Region, Northwest Territories and Wood Buffalo National Park, Alberta [Report]. Birchdale Ecological Ltd. Kaslo, BC. 34 pp.

Lausen, C.L., D. Burles, D. Nagorsen, K. Blejwas, P. Govindarajulu, and L. Friis. 2016. Abstract - Long-eared bat taxonomy: nuclear genetic evidence eliminates the species status of Keen's myotis (*Myotis keenii*). Society for the Northwest Vertebrate Zoology Conference, April 2016. Website: http://thesnvb.org/wp-content/uploads/2016/02/2016_Abstracts.pdf [Accessed July 2016].

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

Lausen, C.L. and R.M.R. Barclay. 2006a. Benefits of living in a building: big brown bats (*Eptesicus fuscus*) in rocks versus buildings. Journal of Mammalogy 87:362-370.

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

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

Lausen, C.L., J.M. Talerico, L.A. Randall, and T.S. Jung. In prep. Morphometrics and plasticity in echolocation calls of little brown bats (*Myotis lucifugus*) at the northern edge of their range.

Lausen, C.L., T.S. Jung, and J.M. Talerico. 2008. Range extension of the northern long-eared bat (*Myotis septentrionalis*) in the Yukon. Northwestern Naturalist 89(2): 115-117.

Lilley, T.M., J.S. Johnson, L. Ruokolainen, E.J. Rogers, C.A. Wilson, S.M. Schell, K.A. Field, and D.M. Reeder. 2016. White-nose syndrome survivors do not exhibit frequent arousals associated with *Pseudogymnoascus destructans* infection. Frontiers in Zoology 13:12.

Lindner, D.L., A. Gargas, J.M. Lorch, M.T. Banik, J. Glaeser, T.H. Kunz, and D.S. Blehert. 2011. DNA-based detection of the fungal pathogen Geomyces destructans in soils from bat hibernacula. Mycologia 103(2): 241-246.

Little, M.E., N.M. Burgess, H. Broders, and L.M. Campbell. 2015. Distribution of mercury in archived fur from little brown bats across Atlantic Canada. Environmental Pollution 207: 52-28.

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

Loeb, S.C. and J.M. O'Keefe. 2011. Bats and gaps: the role of early successional patches in the roosting and foraging ecology of bats. Managing Forest Ecosystems 21: 167-189.

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

Lorch, J.M., J.M. Palmer, D.L. Lindner, A.E. Ballmann, K.G. George, K. Griffin, S. Knowles, J.R. Huckabee, K.H. Haman, C.D. Anderson, P.A. Becker, J.B. Buchanan, J.T. Foster, and D.S. Blehert. 2016. First detection of bat white-nose syndrome in western North America. mSphere Aug 2016, 1(4) e00148-16.

Lorch, J.M., L.K. Muller, R.E. Russell, M. O'Connor, D.L. Lindner, D.S. Blehert. 2013. Distribution and environmental persistence of the causative agent of white-nose syndrome, *Geomyces destructans,* in bat hibernacula of the Eastern United States. Applied and Environmental Microbiology 79:1293-1301.

Mackenzie Valley Land and Water Board (MVLWB). 2015a. Public Registry. Website:

www.mvlwb.ca/Boards/mv/Registry/2015 [Accessed December 2015].

Mackenzie Valley Land and Water Board (MVLWB). 2015b. Issuance of Type A Land Use Permit, Woods Operations, Fort Providence, NT. Mackenzie Valley Land and Water Board, Yellowknife, NT. Website: http://www.mvlwb.ca/Boards/mv/Registry/2015/MV2015W0018/MV2015W0018%20-%20Digaa%20Enterprises%20-%20Issuance%20-%20Type%20A%20Land%20Use%20Permit%20-%20Conditions%20and%20Reasons%20for%20Decisions%20-%20Dec3-15.pdf [Access August 2016].

Mackenzie Valley Land and Water Board (MVLWB). 2015c. Issuance of Type A Land Use Permit, Woods Operations, South Slave, NT. Mackenzie Valley Land and Water Board, Yellowknife, NT. Website: http://www.mvlwb.ca/Boards/mv/Registry/2015/MV2015W0011/MV2015W0011%20-%20Timberworks%20-%20Issuance%20-%20Type%20A%20Land%20Use%20Permit.pdf [Accessed August 2016].

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

Marcot, B.G. 1984. Winter use of some northwestern California caves by western big-eared bats and long-eared myotis. The Murrelet 65: 46.

McAlpine, D.F. 1983. Status and conservation of solution caves in New Brunswick. The New Brunswick Museum, St. John, NB.

McAlpine, D.F., F. Muldoon, G.J. Forbes, A.I. Wandeler, S. Makepeace, H.G. Broders, and J.P. Goltz. 2002. Over-wintering and reproduction by the big brown bat, *Eptesicus fuscus*, in New Brunswick. Canadian Field Naturalist 116:645-647.

McManus, J.J. 1974. Activity and thermal preference of the little brown bat, *Myotis lucifugus*, during hibernation. Journal of Mammalogy 55:844-846.

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.

Messenger, S., C. Rupprecht, and J. Smith. 2003. Bats, emerging virus infections, and the rabies paradigm. Pp. 622-657 *in* T. Kunz and F. Fenton (Eds.). Bat Ecology. University of Chicago Press, Chicago, Illinois. 779 pp.

Meteyer, C.U., M. Valent, J. Kashmer, E.L. Buckles, J.M. Lorch, D.S. Blehert, A. Lollar, D. Berndt, E. Wheeler, C.L. White, and A.E. Ballman. 2011. Recovery of little brown bats (*Myotis lucifugus*) from natural infection with *Geomyces destructans*, white-nose syndrome. Journal of Wildlife Diseases 47: 618-626.

Metheny, J.D., M.C. Kalcounis-Rueppell, C.K. 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*). Behavioural Ecology and Sociobiology 62: 1043-1051.

Meyer, G.A., Senulis, J.A., and J.A., Reinartz. 2016. Effects of temperature and availability of insect prey on bat emergence from hibernation in spring. Journal of Mammalogy web access only DOI: 10. 1093/jmammal/gyw126.

Miller, B., F. Reid, J. Arroyo-Cabrales, A.D. Cuarónand, and P.C. de Grammont. 2008. *Eptesicus fuscus*. The IUCN Red List of Threatened Species. Version 2014.3. Website: www.iucnredlist.org [Accessed 1 March 2015].

Mills, R.S., G.W. Barrett, and M.P. Farrell. 1975. Population dynamics of the big brown bat (*Eptesicus fuscus*) in Southwestern Ohio. Journal of Mammalogy 56:591-604.

Moosman, P.R. Jr., J.P. Veilleux, G.W. Pelton, and H.H. Thomas. 2013. Changes in capture rates in a community of bats in New Hampshire during the progression of white-nose syndrome. Northeastern Naturalist 20:552-558.

Nadine-Davis, S.A., W. Huang, J. Armstrong, G.A. Casey, C. Bahloul, N. Tordo, and A.I. Wandeler. 2001. Antigenic and genetic divergence of rabies viruses from bat species indigenous to Canada. Virus Research 74:139-156.

Nagorsen, D.W. and R. M. Brigham. 1993. Bats of British Columbia. UBC Press, Vancouver, BC. 164 pp.

Nagorsen, D.W., A.A. Bryant, D. Kerridge, G. Roberts, A. Roberts, and M.J. Sarell. 1993. Winter bat records for British Columbia. Northwestern Naturalist 74:61-66.

NatureServe. 2014. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Website: http://explorer.natureserve.org [Accessed January 2015].

Naughton, D. 2012. The natural histroy of Canadian mammals. Canadian Museum of Nature, University of Toronto Press, Toronto, ON.

Navo, K.W., S.G. Henry and T.E. Ingersoll. 2002. Observations of swarming by bats and band recoveries in Colorado. Western North American Naturalist 62:124-126.

Neilson, A.L. and M.B. Fenton. 1994. Responses of little brown myotis to exclusion and to bat houses. Wildlife Society Bulletin 22: 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. 2006. Journal of Mammalogy 87:470-479.

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 162:139-147.

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: 335-427.

Norquay, K.J.O. and C.K.R. Willis. 2014. Hibernation phenology of *Myotis lucifugus*. Journal of Zoology 294:85-92.

Norquay, K.J.O., F. Martinez-Nuñez, J.E. Dubois, K.M. Monson, and C.K.R. Willis. 2013. Long-distance movements of little brown bats (*Myotis lucifugus*). Journal of Mammalogy 94: 506-515.

Northwest Territories Geoscience Office. 2013. Northern mineral showings database. Government of the Northwest Territories, Yellowknife, NT. Website: http://www.nwtgeoscience.ca/services/geological_library.html [Accessed August 2016].

NWT News/North Online. 2014. Setting a baseline for South Slave bats. Website: www.nnsl.com/frames/newspapers/2014-08/aug18_14bat.html# [Accessed November 2015].

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

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

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

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

Pacifici, M., L. Santini, M. Di Marco, D. Baisero, L. Francucci, G.G. Marasini, P. Visconti, and C. Rondinini. 2013. Generation length for mammals. Nature Conservation 5: 89-94.

Park, A. and H. Broders. 2012. Distribution and roost selection of bats on Newfoundland. Northeastern Naturalist 19: 165-176.

Parker, D.I., B.E. Lawhead and J.A. Cook. 1997. Distributional limits of bats in Alaska. Arctic 50:256-265.

Pauli, B.P., P.A. Zollner, G.S. Haulton, G. Shao, and G. Shao. 2015. The simulated effects of timber harvest on suitable habitat for Indiana and northern long-eared bats. Ecosphere 6(4): 1-24.

Patriquin, K.J. and R.M.R. Barclay. 2003. Foraging by bats in cleared, thinned and unharvested boreal forest. Journal of Applied Ecology 40:646–657.

Pearce, R.D. and T.J. O'Shea. 2007. Ectoparasites in an urban population of big brown bats (*Eptesticus fuscus*) in Colorado. Ectoparasitology 93:518-530.

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

Perry, R.W. 2013. A review of factors affecting cave climates for hibernating bats in temperate North America Environmental Reviews 21:28–39.

Player, D., pers. comm. 2016. Email communication to B. Fournier. August 2016. Senior Wildlife Biologist, Matrix Solutions.

Puechmaille, S.J., G. Wibbelt, V. Korn, H. Fuller, F. Forget, K. Mühldorfer, A. Kurth, W. Bogdanowicz, C. Borel, T. Bosch, T. Cherezy, M. Drebet, T. Görföl, A-J. Haarsma, F. Herhaus, G. Hallart, M. Hammer, C. Jungmann, Y. Le Bris, L. Lutsar, M. Masing, B. Mulkens, K. Passior, M. Starrach, A. Wojtaszewski, U. Zöphel, and E.C. Teeling. 2011. Pan-European distribution of white-nose syndrome fungus (*Geomyces destructans*) not associated with mass mortality. PLoSONE 6: e19167. doi: 10.1371/journal/pone.0019167.

Quay, W.B. 1948. Notes on some bats from Nebraska and Wyoming, Journal of Mammalogy 29:181-182.

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

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: 77-84.

Rancourt, S.J., M.I. Rule, and M.A. O'Connell. 2007. Maternity roost site selection of big brown bats in ponderosa pine forest of the Channeled Scablands of northeastern Washington State, USA. Forest Ecology and Management 248:183-192.

Randall, J. and H.G. Broders. 2014. Identification and characterization of swarming sites used by bats in Nova Scotia, Canada. Acta Chiropterologica 16:109-116.

Randall, L.A., T.S. Jung, and R.M.R. Barclay. 2014. Roost-site selection and movements of little brown myotis (*Myotis lucifugus*) in southwestern Yukon. Northwestern Naturalist 95:312-317.

Randall, L., R. Barclay, M. Reid, and T. Jung. 2011. Recent infestation of forest stands by spruce beetles do not predict habitat use by little brown bats (*Myotis lucifugus*) in southwestern Yukon, Canada. Forest Ecology and Management 261: 1950-1956.

Ratcliffe, J.M. and J.W. Dawson. 2003. Behavioural flexibility: the little brown bat, *Myotis lucifugus*, and the northern long-eared bat, *M. septentrionalis*, both glean and hawk prey. Animal Behaviour 66:847-856.

Ratcliffe, J.M., M.B. Fenton, and S.J. Shettleworth. 2006. Behavioural flexibility positively correlated with relative brain volume in predatory bats. Brain, Behaviour and Evolution 67: 165-176.

Reeder, W.G. 1965. Occurrence of the big brown bat in southwestern Alaska. Journal of Mammalogy 46:332-333.

Reichard, J.D., N.W. Fuller, A.B. Bennett, S.R. Darling, M.S. Moore, K.E. Langwig, E.D. Preston, S. von Oettingen, C.S. Richardson, and D.S. Reynolds. 2014. Interannual survival of *Myotis lucifugus* (Chiroptera: Vespertilionidae) near the epicenter of white-nose syndrome. Northeastern Naturalist 21(4): 56-59.

Reimer, J.P. 2013. Nocturnality under the midnight sun: behavioural adaptations of the little brown bat (*Myotis lucifugus*) at 60°N latitude. M.Sc. Thesis, University of Calgary, Calgary, AB. 108 pp.

Reimer, J.P. pers. comm. 2015. January – March 2015, observations during field work. University of Calgary, Department of Biology, Calgary, AB.

Reimer, J.P. pers. comm. 2016. Email correspondence with C. Singer and J. Wilson (provision of unpubl. data). Assistant Zoologist, University of Alaska Anchorage, Anchorage, AK.

Reimer, J.P. unpubl. data. 2012. Radiotelemetry locations of *Myotis lucifugus* tagged at the Thebacha maternity colony, Northwest Territories. University of Calgary, Calgary, AB.

Reimer, J., unpubl. data. 2013a. Acoustic monitoring and morphometric measurements of *Eptesicus fuscus, M. lucifugus* and *M. septentrionalis* in the South Slave region of the NWT. University of Calgary, Calgary, AB.

Reimer, J., unpubl. data. 2013b. Environmental conditions and exit counts at a *M. lucifugus* maternity roost, Thebacha cabins, Salt River, NWT. University of Calgary, Calgary, AB.

Reimer, J. unpubl. photos. 2013. Photos of *E. fuscus*, *M. lucifugus* and *M. septentrionalis* in Wood Buffalo National Park and the South Slave region, NT. University of Calgary, Calgary, AB.

Reimer, J.P. and L. Kaupas. 2013. South Slave region bat research summary 2013 [Report]. Prepared for Environment and Natural Resources, Government of the Northwest Territories, Fort Smith, NT. University of Calgary, Calgary, AB. 8 pp.

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

Rydell, J. 1991. Occurrence of bats in northernmost Sweden (656N) and their feeding ecology in summer. Journal of Zoology, London 227: 517-529.

Rysgaard, G.N. 1942. A study of the cave bats of Minnesota with special reference to the large brown bat, *Eptesicus fuscus fuscus* (Beauvois). American Midland Naturalist 28:245-267.

Sahtú Renewable Resources Board (SRRB) and Species at Risk Secretariat (SARS). 2013. Report of the Sahtú Species at Risk Terminology Workshop. Website: http://www.nwtspeciesatrisk.ca/sites/default/files/final_report_of_sar_sahtu_workshop_13-11-01.pdf [Accessed December 2015].

Sasse, D. and P. Pekins. 1996. Summer roosting ecology of northern long-eared bats (*Myotis septentrionalis*) in the White Mountain National Forest. Pp. 91-101 *in* R. Barclay and M. Brigham (Eds.). Bats and Forests Symposium, October 19-21, 1995, Victoria, BC. Working Paper 23/1996. British Columbia Ministry of Forests, Victoria, BC. 292 pp.

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

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

Scotter, G.W., N.M. Simmons, H.L. Simmons, and S.C. Zolted. 1971. Ecology of the South Nahanni and Flat River areas. Submitted to the National and Historic Parks Branch. Canadian Wildlife Service, Edmonton, AB. 186 pp.

Secord, A.L., K.A. Patnode, C. Carter, E. Redman, D.J. Gefell, A.R. Major, and D.W. Sparks. 2015. Contaminants of emerging concern in bats from the Northeastern United States. Archives of Environmental Contamination and Toxicology 69: 411-421.

Shelley, V., S. Kaiser, E. Shelley, T. Williams, M. Kramer, K. Haman, K. Keel, and H.A. Barton. 2011. Evaluation of strategies for the decontamination of equipment for *Geomyces destructans*, the causative agent of white-nose syndrome (WNS). Journal of Cave and Karst Studies 75: 1–10.

Sherwin, H.A., W.I. Montgomery, and M.G. Lundy. 2012. The impact and implications of climate change for bats. Mammal Review, doi: 10.1111/j.1365-2907.2012.0

Silvis, A., W.M. Ford, and E.R. Britzke. 2015. Effects of hierarchical roost removal on northern long-eared bat (*Myotis septentrionalis*) maternity colonies. PLoS ONE 10(1): e0116356.

Slough, B.G. and T.S. Jung. 2008. Observations on the natural history of bats in the Yukon. Northern Review 29: 127-150.

Slough, B.G., T.S. Jung, and C.L. Lausen. 2014. Acoustic survey reveals hoary bat (*Lasiurus cinereus*) and long-legged myotis (*Myotis volans*) in Yukon. Northwestern Naturalist 95:176-185.

Smith, R.W. 1940. The land mammals of Nova Scotia. American Midland Naturalist 24:213-241.

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

South Slave Divisional Education Council. 2012. Dëne Dédlıné Yatıé ʔerehtł'ischo Denínu Kúę́ Yatıé – Chipewyan Dictionary. South Slave Divisional Education Council, Fort Smith, NT. 369 pp. Website: http://www.ssdec.nt.ca/ablang/ablanguage/chiptionary/Chipewyan%20Dictionary.pdf [Accessed July 2016].

South Slave Divisional Education Council. 2014. Dëné Sołıné Yatıé ʔerehtł'ís Łuskëlk'e T'ıné Yatıé – Chipewyan Dictionary. South Slave Divisional Education Council, Fort Smith, NT. 487 pp. Website: http://www.ssdec.nt.ca/ablang/ablanguage/lkchipdictionary/Chipewyan_Dictionary-Linked/Chipewyan_Dictionary.pdf [Accessed July 2016].

South Slave Divisional Educatıon Council. 2009. South Slavey Topical Dictionary Kátł'odehche Dialect. South Slave Divisional Education Council, Fort Smith, NT. 203 pp. Website: http://www.ssdec.nt.ca/Dictionary/dictionary.pdf [Accessed July 2016].

Soya, A.J., N.M. Tchevbakova, N.H.F. French, M.D. Flanigan, H.H. Shugart, B.J. Stocks, A.I. Sukhinin, E.I. Parfenova, F.S. Chapin III, and P.W. Stackhouse Jr. 2007. Climate-induced boreal forest change: predictions versus current observations. Global and Planetary Change 56: 274-296.

Speakman, J.R. and A. Rowland. 1999. Preparing for inactivity: how insectivorous bats deposit a fat store for hibernation. Proceedings of the Nutrition Society 58: 123-132.

Speakman, J.R. and D.W. Thomas. 2003. Physiological ecology and energetics of bats. Pp. 430-492 *in* T.H. Kunz and M.B. Fenton (Eds.). Bat Ecology. University of Chicago Press, Chicago, IL.

Speakman, J.R., J. Rydell, P.I. Webb, J.P. Hayes, G.C. Hays, I.A.R. Hulbert, and R.M. McDevitt. 2000. Activity patterns of insectivorous bats and birds in northern Scandinavia (69ºN), during continuous mid-summer daylight. Oikos 88: 75-86.

Speakman, J.R., P.I. Webb and P.A. Racey. 1991. Effects of disturbance on the energy expenditure of hibernating bats. Journal of Applied Ecology 28: 1087-1104.

Species at Risk Committee (SARC). 2015. Detailed instructions for the preparation of a SARC status report: scientific knowledge component. Species at Risk Committee, Yellowknife, NT. Website: http://www.nwtspeciesatrisk.ca/sites/default/files/2015_may_14_sarc_instructions_sk_final.pdf [Accessed August 2016].

Species at Risk Public Registry. 2015. Bats and white-nose syndrome in Canada. Government of Canada. Website: http://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=073DC653-1 [Accessed November 2015].

Talerico, J. 2008. The behaviour, diet and morphology of little brown bats (*Myotis lucifugus*) near the northern extent of its range in Yukon, Canada. M.Sc. Thesis, University of Calgary, Calgary, AB. 104 pp.

Taylor, D.A.R. 2006. Forest management & bats. Bat Conservation International. Website: www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_009962.pdf [Accessed November 2015].

Taylor, L.R. 1963. Analysis of the effect of temperature on insects in flight. Journal of Animal Ecology 32: 99-117.

Thomas, D.W. 1993. Bats, mines, and politics. Bats 2:10-1.

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

Thomas, D.W., M. Dorais, and J. Bergeron. 1990. Winter energy budgets and cost of arousals for hibernating little brown bats, *Myotis lucifugus*. Journal of Mammalogy 71:475-479.

Thomas, D.W., M.B. Fenton, and R.M.R. Barclay. 1979. Social behavior of the little brown bat, *Myotis lucifugus*. Behavioral Ecology and Sociobiology 6:129-136.

Timpone, J.C., J.G. Boyles, K.L. Murray, D.P. Aubrey, and L.W. Robbins. 2010. Overlap in roosting habits of Indian bats (*Myotis sodalist*) and northern bats (*Myotis septentionalis*). American Midland Naturalist 163:115-123.

Turner, G.G., D.M. Reeder, and J.T.H. Coleman. 2011. A five-year assessment of mortality and geographic spread of white-Nose syndrome in North American bats, with a look at the future. Update on white-nose syndrome in bats. Bat Research News 52:13-27.

Tuttle, M.D. and D. Stevenson. 1982. Growth and survival of bats. Pp. 105-150 *in* T.H. Kunz (Ed.). Ecology of Bats. Springer US, New York, NY.

United States Fish and Wildlife Service (USFWS). 2015. Endangered and threatened wildlife and plants; threatened species. Status of the northern long-eared bat with 4(d) rule; final rule and interim rule. 50 CFR Part 17. Website: http://www.fws.gov/midwest/endangered/mammals/nleb/pdf/FRnlebFinalListing02April2015.pdf [Accessed November 2015].

United States Fish and Wildlife Service (USFWS). 2016. Northern long-eared bat (Myotis septentrionalis). Website: http://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=A0JE [Accessed September 2016].

United States Fish and Wildlife Service (USFWS) and partners (*et al*.). 2016. White nose syndrome. Web site: www.whitenosesyndrome.org [Accessed August 2016].

Vanderwolf, K.J., D.F. McAlpine, G.J. Forbes, and D. Malloch. 2012. Bat populations and cave microclimate prior to and at the outbreak of white-nose syndrome in New Brunswick. The

Canadian Field-Naturalist 126: 125-134.

van Zyll de Jong, C.G. 1979. Distribution and systematic relationships of long-eared myotis in western Canada. Canadian Journal of Zoology 57:987-994.

van Zyll de Jong, C.G. 1985. Handbook of Canadian mammals. Volume 2: Bats. National Museum of Natural Science, National Museum of Canada, Ottawa, ON. 212 pp.

Verant, M.L., J.G. Boyles, W. Waldrep Jr., G. Wibbelt, and D.S. Blehert. 2012. Temperature-dependent growth of *Geomyces destructans*, the fungus that causes bat white-nose syndrome. PloS ONE 7: e46280. doi: 10.1371/journal.pone.0046280.

Verant, M.L., C.U. Meteyer, J.R. Speakman, P.M. Cryan, J.M. Lorch, and D.S. Blehert. 2014. White-nose syndrome initiates a cascade of physiologic disturbances in the hibernating bat host. BMC Physiology 14:10.

Vonhof, M.J. and D. Hobson. 2001. Alberta Species at Risk Report, No. 4: Survey of the bats of central and northwestern Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Service, Edmonton, Ab. 33 pp.

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

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: 674-684.

Vonhof. M.J., S. McNalley, and A. Yu. 1997. Roosting habitat requirements of northern long-eared bats (*Myotis septentrionalis*) in northeastern British Columbia: the Fort Nelson River and highway 77 area. [Report] Prepared for Ministry of Environment, Lands and Parks, Fort St. John, BC. 63 pp.

Vonhof, M.J., L. Wilkinson. 1999. Roosing habitat requirements of Northern Long-eared Bats (*Myotis septentrionalis*) in the boreal forests of northeastern British Columbia: Year 2. [Report] Prepared for Ministry of Environment, Lands and Parks, Fort St. John, B.C. 87 pp.

Waldien, D.L. and J.P. Hayes. 2001. Activity areas of female long-eared myotis in coniferous forests in western Oregon. Northwest Science 75:307-314.

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

Webb, P.I., J.R., Speakman, and P.A. Racey. 1996. How hot is a hibernaculum? A review of the temperatures at which bats hibernate. Canadian Journal of Zoology 74: 761-765.

Western Bat Working Group. 2014. Unpublished survey results: Vulnerability assessment of western bat species to white-nose syndrome. Western Bat Working Group Biennial Meeting, 1-4 April 2013, Santa Fe, NM.

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

Whitaker, J.O. Jr., C. Maser and L.E. Keller. 1977. Food habits of bats of western Oregon. Northwestern Science 51:46-55.

White, D.H. and J.T. Seginak. 1987. Cave gate design for use in protecting endangered bats. Wildlife Society Bulletin 15:445-449.

Wilder, A.P. 2014. Spatial, ecological and genetic correlates of the geographic expansion of an infectious disease, white-nose syndrome in bats. PhD Dissertation, Boston University, Boston, MA. 136 pp.

Wilder, A.P. pers. comm. 2015. Email correspondence to J. Reimer. January 2014. Postdoctoral Research Associate, Department of Biology, Boston University, Boston, MA.

Wilder, A.P., T.H. Kunz, and M.D. Sorenson. 2015. Population genetic structure of a common host predicts the spread of white-nose syndrome, an emerging infectious disease in bats. Molecular Ecology 24:5495-5506.

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

Wilkinson, L.C., P.F.J. Garcia, and R.M.R. Barclay. 1995. Bat survey of the Liard River watershed in northern British Columbia. Report prepared for Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria, BC. 41 pp.

Willis, C.K.R., A.K. Menzies, J.G. Boyles, and M.S. Wojciechowski. 2011. Evaporative water loss is a plausible explanation for mortality of bats from white-nose syndrome. Integrative and Comparative Biology 51:364-373.

Wilson, D.E. and D.M. Reeder (Eds.). 2005. Mammal species of the world: a taxonomic and geographic reference. Third edition. The Johns Hopkins University Press, Baltimore. Two volumes. 2,142 pp. Website: http://www.bucknell.edu/msw3/ [Accessed March 2015] .

Wilson, J.M. 2014. Bat monitoring in the NWT [Research Summary Report]. Associate with research permit number WL500121. Wildlife Division, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 6 pp.

Wilson, J.M. 2016. Bat monitoring in the Northwest Territories: research progress report for April 2015-March 2016, associated with research permit number WL500317. Wildlife Division, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 3 pp.

Wilson, J.M. pers. comm. 2015. Phone and email correspondence to J. Reimer. February 2015. Wildlife Biologist – Species at Risk, Environment and Natural Resources, Wildlife Division, Government of the Northwest Territories, Yellowknife, NT.

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

Wojciechowski, M.S., M. Jefimow, and E. Tegowska. 2007. Environmental conditions, rather than season, determine torpor use and temperature selection in large mouse-eared bats (*Myotis myotis*). Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology 147:828-840.

Wood Buffalo National Park. unpubl. report. 1981. Karst 3-10, airphoto analysis 1979. Received from S. Irwin, Resource Management Officer, Wood Buffalo National Park, Fort Smith, NT. Email contact: Sharon.Irwin@pc.gc.ca.

Yates, D.E., E.M. Adams, S.E. Angelo, D.C. Evers, J. Schmerfeld, M.S. Moore, T.H. Kunz, T. Divoll, S.T. Edmonds, and C. Perkins. 2014. Mercury in bats from the northeastern United States. Ecotoxicology 23(1): 45-55.

Zimmerling, J.R. and C.M. Francis. 2016. Bat mortality due to wind turbines in Canada. Journal of Wildlife Management (online), July 26, 2016. Website: http://onlinelibrary.wiley.com/doi/10.1002/jwmg.21128/full [Accessed August 2016].

Appendix A

Description

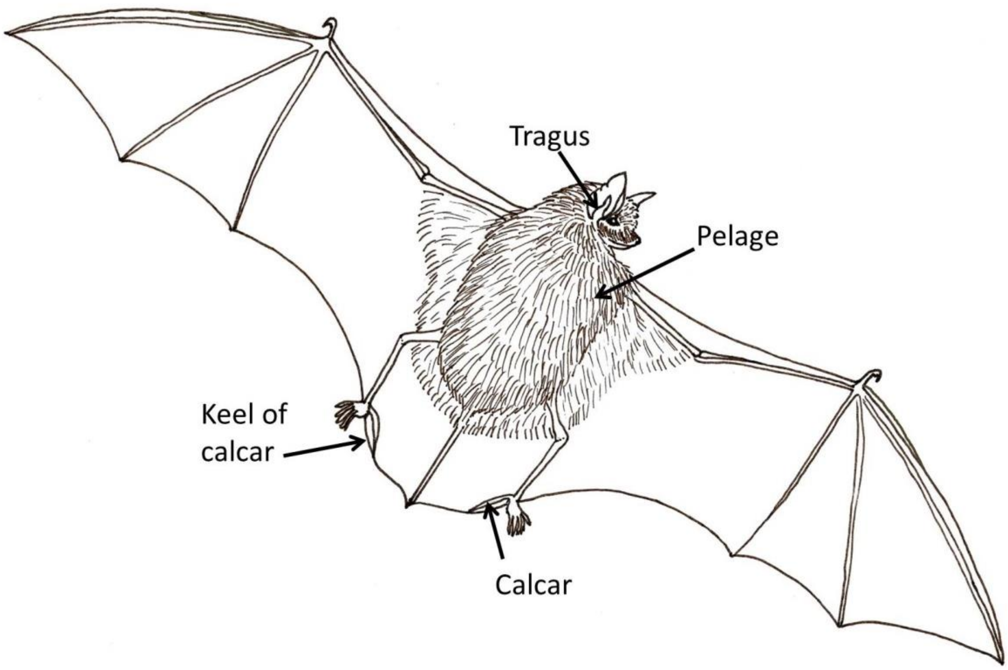

Figure 27. Depiction of key anatomical terms in text. Figure courtesy B. Fournier.

Calculating generation time

Generation time (generation length) for each species was calculated using the following equation, as used by Pacifici *et al.* (2013) and IUCN (2014):

$$GL = R_{span} * z + AFR$$

GL is generation length

$\boldsymbol{R_{span}}$ is the species-specific reproductive lifespan (maximum age minus *AFR*)

z is a constant that accounts for the survivorship and relative fecundity of young verses old individuals in the population. Adequate data was not available to calculate this value for each species, we therefore used a z-value of 0.29 as calculated by Pacifici *et al.* (2013) based on the relationship between generation length and reproductive lifespan for 221 mammal species.

AFR is the age of first reproduction, which we estimated for each species at 640 days. All five species are physically mature enough to reproduce after their first year (365 days), however, there are many environmental variables that cause females to delay reproduction until their second year (see *Lifecycle and reproduction*, p. 40). This estimation assumes that 75% of the population delays reproduction until their second year, although the exact value for each species is unknown.

Table A.1: Species-specific calculation values for generation time of the big brown bat (*Eptesicus fuscus*), long-eared myotis (*Myotis evotis*), little brown myotis (*M. lucifugus*), northern myotis (*M. septentrionalis*) and long-legged myotis (*M. volans*).

Scientific Name	**Max. Age** (days)[1]	R_{span} (days)	**AFR** (days)	**z**	**GL** (days)	**GL** (years)[2]
Eptesicus fuscus	6,935	6,295	640	0.29	2,466	6.8
Myotis evotis	8,030	7,390	640	0.29	2,783	7.6
Myotis lucifugus	12,410	11,770	640	0.29	4,053	11.1
Myotis septentrionalis	6,935	6,295	640	0.29	2,446	6.8
Myotis volans	7,665	7,025	640	0.29	2,677	7.3

[1] Maximum ages used for the calculation were: *Eptesicus fuscus* 19.5 years (Beer 1955; Cockrum 1956); *Myotis evotis* 22 years (Navo et al. 2002; Tuttle and Stevenson 1982); *Myotis lucifugus* 34 years (Davis and Hitchcock 1965; Keen and Hitchcock 1980); *Myotis septentrionalis* 19 years (Kurta 1995 in Wilkinson and South 2002); and *Myotis volans* 21 years (Tuttle and Stevenson 1982).

[2] Generation times calculated for each species are comparable to the values estimated by Pacifici *et al.* (2013); *Eptesicus fuscus* 6.6 years; *Myotis evotis* 5.8 years; *Myotis lucifugus* 11.3 years; *Myotis septentrionalis* 5.8 years; and *Myotis volans* 4.1 years. Different values resulted from using some different estimates for maximum age and age at first reproduction.

Regional/cultural information

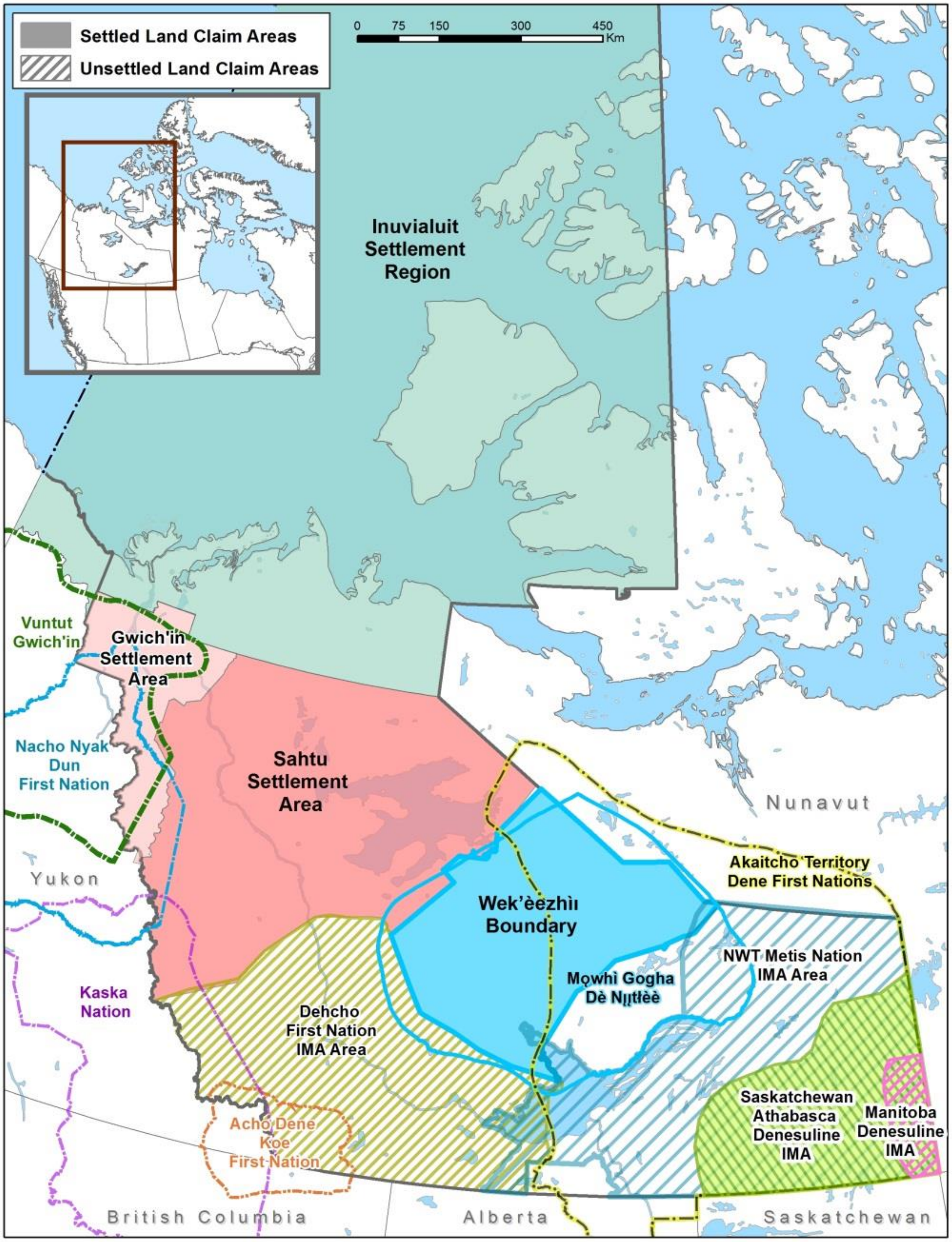

Figure 28. Settlement areas in the NWT.