COSEWIC
Assessment and Status Report

on the

Little Brown Myotis
Myotis lucifugus

Northern Myotis
Myotis septentrionalis

Tri-colored Bat
Perimyotis subflavus

in Canada

ENDANGERED
2013

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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. xxiv + 93 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. February 2012. Technical summary and supporting information for an emergency assessment of the Little Brown Myotis *Myotis lucifugus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 29 pp.

COSEWIC. February 2012. Technical summary and supporting information for an emergency assessment of the Northern Myotis *Myotis septentrionalis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 24 pp.

COSEWIC. February 2012. Technical summary and supporting information for an emergency assessment of the Tri-colored Bat *Perimyotis subflavus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 25 pp.

Production note:
COSEWIC would like to acknowledge Graham Forbes for writing the status report on the Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*M. septentrionalis*), and Tri-colored Bat (*Perimyotis subflavus*) in Canada, prepared under contract with Environment Canada. This status report was overseen and edited by Justina Ray, Co-chair of the COSEWIC Terrestrial Mammals Specialist Subcommittee.

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Cover illustration/photo:
Little Brown Myotis, Northern Myotis and Tri-colored Bat — Photograph of *Myotis* bats, several of which have the white muzzle typical of White-nose Syndrome. Photo taken March 17, 2011, Berryton Cave, New Brunswick. (photo used with permission: K. Vanderwolf, NB Museum).

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COSEWIC
Assessment Summary

Assessment Summary – November 2013

Common name
Little Brown Myotis

Scientific name
Myotis lucifugus

Status
Endangered

Reason for designation
Approximately 50% of the global range of this small bat is found in Canada. Subpopulations in the eastern part of the range have been devastated by White-nose Syndrome, a fungal disease caused by an introduced pathogen. This disease was first detected in Canada in 2010, and to date has caused a 94% overall decline in known numbers of hibernating *Myotis* bats in Nova Scotia, New Brunswick, Ontario, and Quebec. The current range of White-nose Syndrome has been expanding at an average rate of 200-250 kilometres per year. At that rate, the entire Canadian population is likely to be affected within 12 to 18 years. There is no apparent containment of the northward or westward spread of the pathogen, and proper growing conditions for it exist throughout the remaining range.

Occurrence
Yukon, Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Status history
Designated Endangered in an emergency assessment on February 3, 2012. Status re-examined and confirmed in November 2013.

Assessment Summary – November 2013

Common name
Northern Myotis

Scientific name
Myotis septentrionalis

Status
Endangered

Reason for designation
Approximately 40% of the global range of this northern bat is in Canada. Subpopulations in the eastern part of the range have been devastated by White-nose Syndrome, a fungal disease caused by an introduced pathogen. This disease was first detected in Canada in 2010 and to date has caused a 94% overall decline in numbers of known hibernating Myotis bats in Nova Scotia, New Brunswick, Ontario, and Quebec hibernacula compared with earlier counts before the disease struck. Models in the northeastern United States for Little Brown Myotis predict a 99% probability of functional extirpation by 2026. Given similar life history characteristics, these results are likely applicable to this species. In addition to its tendency to occur in relatively low abundance levels in hibernacula, there is some indication this species is experiencing greater declines than other species since the onset of White-nose Syndrome. The current range of White-nose Syndrome overlaps with approximately one third of this species' range and is expanding at an average rate of 200 to 250 kilometres per year. At that rate, the entire Canadian population will likely be affected within 12 to18 years. There is no apparent containment of the northward or westward spread of the pathogen, and proper growing conditions for it exist throughout the remaining range.

Occurrence
Yukon, Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Status history
Designated Endangered in an emergency assessment on February 3, 2012. Status re-examined and confirmed in November 2013.

Assessment Summary – November 2013

Common name
Tri-colored Bat

Scientific name
Perimyotis subflavus

Status
Endangered

Reason for designation
This bat is one of the smallest bats in eastern North America. Approximately 10% of its global range is in Canada, and it is considered rare in much of its Canadian range. Declines of more than 75% have occurred in the known hibernating populations in Quebec and New Brunswick due to White-nose Syndrome. This fungal disease, caused by an invasive pathogen, was first detected in Canada in 2010, and has caused similar declines in Little Brown Myotis and Northern Myotis in eastern Canada and the northeastern United States. Most of the Canadian range of the species overlaps with the current White-nose Syndrome range, and further declines are expected as more hibernacula continue to become infected.

Occurrence
Ontario, Quebec, New Brunswick, Nova Scotia

Status history
Designated Endangered in an emergency assessment on February 3, 2012. Status re-examined and confirmed in November 2013.

COSEWIC
Executive Summary

Little Brown Myotis
Myotis lucifugus

Northern Myotis
Myotis septentrionalis

Tri-colored Bat
Perimyotis subflavus

Wildlife Species Description and Significance

All three bat species are small (average 7.4 g), brown-pelaged, insectivorous species of the Family Vespertilionidae. Little Brown Myotis (*Myotis lucifugus*) likely is the most common bat species in Canada and the most familiar of the three species to the public because they often use buildings as day-roosts and forage in areas where they are visible (e.g., over lakes, aound streetlights, etc.). Northern Myotis (*M. septentrionalis*) are common in forests and Tri-colored Bat (*Perimyotis subflavus*) is found in variety of habitats, but is rarer than the other two. Public concern over zoonotic diseases (*i.e.*, rabies, histoplasmosis), noise, and hygiene has resulted in periodic extermination of maternity colonies and/or elimination of their roosts. Bats are predators of insects, some of which are considered pests in the agriculture and forestry sectors, and provide an important ecological service in this regard.

Distribution

In Canada, *Myotis lucifugus* and *M. septentrionalis* occur from Newfoundland to British Columbia, and northward to near the treeline in Labrador, Northwest Territories (NT) and the Yukon. *Perimyotis subflavus* occurs in Nova Scotia (NS), New Brunswick (NB), Quebec, and Ontario. All three species occur in much of the eastern half of the United States (US), and *M. lucifugus* extends to the US west coast, including Alaska.

Habitat

All three species overwinter in cold and humid hibernacula (caves/mines). Their specific physiological requirements limit the number of suitable sites for overwintering. In the east, large numbers (*i.e.*, >3000 bats) of several species typically overwinter in relatively few hibernacula. In the west, there are fewer known hibernacula, and numbers appear lower per site. Females establish summer maternity colonies, often in buildings (mainly *Myotis lucifugus*), or large-diameter trees. Foraging occurs over water (mainly *M. lucifugus, P. subflavus*), along waterways, forest edges, and in gaps in the forest (mainly *M. septentrionalis*). Large open fields or clearcuts generally are avoided. In autumn, bats return to hibernacula, which may be hundreds of kilometres from their summering areas, swarm near the entrance, mate, and then enter that hibernaculum, or travel to different hibernacula to overwinter.

Biology

Breeding is promiscuous. Females produce one pup (potentially two in *Perimyotis subflavus*) after one year of age. Maximum recorded longevity is 15 years (*P. subflavus*) to >30 years (*Myotis lucifugus*). Survivorship is low in year one, then highly variable (e.g., 0.6-0.9) afterwards. Generation time is estimated as 5-10 years for *M. lucifugus* and *M. septentrionalis*, and 5-7 years for *P. subflavus*. Finite population growth rate is slow, with a range of 0.98-1.2.

Population Sizes and Trends

Population sizes are unknown but were likely over a million for each of the *Myotis* species prior to the 2010 arrival in Canada of White-nose Syndrome (WNS), a disease caused by a cold-loving fungus *Pseudogymnoascus destructans* (*Pd*), likely originating in Europe. *M. lucifugus* and *M. septentrionalis* were considered to be common in much of their range in eastern Canada and northeastern US, and are still common in Canada outside the range of WNS. *Perimyotis subflavus* was considered rare to uncommon in parts of Canada. Approximately 95% of the hibernating *Myotis* bats that have been counted occur in the range from Nova Scotia to Manitoba, with relatively few bats having been recorded west of Manitoba. However, the number in the north and west is considered an underestimate and the proportion of the populations of the two *Myotis* that has been affected by WNS since its arrival in Canada is unknown. During 2006-2012, an estimated 5.7-6.7 million bats in eastern North America died due to WNS. *M. lucifugus* is predicted to be functionally extirpated (*i.e.,* <1% of former population) by 2026 in northeastern US. The same prediction likely applies to *M. septentrionalis* because of similar life history traits. *P. subflavus* populations have declined in the US by approximately 75%.

WNS has been recorded in Ontario, Quebec, NB, NS, and Prince Edward Island (PEI). Most population trend data are derived from counts in some of the few, known hibernacula. Data on *Myotis lucifugus* and *M. septentrionalis* often are combined but percent change is assumed to be equal between species. Declines recorded at hibernacula having pre- and post-WNS data have been catastrophic: 93% (Ontario); 99% (NB), 93% (NS) for *Myotis* combined, and 98% for *M. lucifugus* and 99.8% for *M. septentrionalis* in Quebec*.* The total decline in *Myotis* bats known to be present in NS, NB, Ontario, and Quebec hibernacula from the time of WNS arrival to most recent data for the same sites is 94% (86,952 to 5,225). Relatively few *Perimyotis subflavus* occur in Canada and it is difficult to determine trends; declines of 94% and 75% were recorded in caves in Quebec and NB, respectively. Trend data on bats in summer are limited but are similar to winter data, suggesting winter hibernacula data likely are an accurate reflection of declines in the population. Extent of occurrence has not declined, and may not in the future if very low numbers persist across the species' ranges. Major population declines have not been reported outside WNS range.

WNS was first recorded in Canada in spring 2010, and has spread in all directions from the epicentre in northern New York at a rate of 200-250 km/yr. There is uncertainty about the rate of spread to the western range of the two *Myotis* species. The amount of east-west bat movements, and the wintering ecology and hibernacula conditions that may affect the ecology of the disease in western and northern Canada, are largely unknown. However, predictions that WNS will spread throughout the range of both species rest upon: 1) no evidence of containment to date; 2) evidence that abiotic conditions in western hibernacula are conducive to *Pd* growth; and 3) evidence that hibernacula with lower bat densities are still susceptible to WNS. Model predictions and present rate of spread suggest that WNS will reach the western edge of *M. lucifugus* range in 12-18 yrs, and western edge of *M. septentrionalis* in 12-15 yrs, or within three generations, which is 15-30 yrs. There are also concerns WNS may move more quickly to western Canada if transmitted via human clothing from infected caves. The Canadian range of *P. subflavus* already is contained within WNS range.

Rescue effect is not likely because mortality is high in adjacent areas of the US and any future immigrants likely will be vulnerable to *Pd*. A few sites near the epicentre have possibly stabilized at approximately 1,000 bats for several years (albeit following >90% decline), but it is unknown if these numbers indicate survival, or movement between hibernacula. There is the hope that some individuals have genetically based resistance to WNS and they will survive and reproduce resistant offspring. However, the slow population growth rate of all three species means populations would take many generations to recover.

Threats and Limiting Factors

Other threats besides WNS include colony eradication, chemical contamination, change in forest structure, and wind turbines. Although cases of colony eradication have been documented (mainly chemical or physical destruction of maternity colonies of *Myotis lucifugus* in buildings), the overall number of colonies exterminated, or impacts on the larger-scale population is unknown. The extent of disturbance by people on hibernating bats and the impacts of chemical contamination on bats, or insecticide on prey availability, are unknown. To date, the impact of wind turbines is highly variable among sites, but generally they have been less of a mortality factor on the three species than on other bat species that conduct long-distance migration. There is potential concern for *M. lucifugus* in some regions of Canada where higher mortality has been recorded.

Protection, Status, and Ranks

Regulations protecting bats vary across their range; removal of maternity colonies is permitted but some hibernacula are closed to the public. Ontario listed *M. lucifugus* and *M. septentrionalis* as Endangered, due to WNS, in autumn 2012. Both NB and NS listed all three species as Endangered in summer 2013.

NatureServe ranks for *Perimyotis subflavus* are Global; G3 (vulnerable), National; N2N3, and S1 (critically imperilled) to S3 at the sub-national level. *Myotis lucifugus* (G3; N3) and *M. septentrionalis* (G1G3; N2N3) are ranked sub-nationally as apparently secure-secure (S4-S5) over much of their range, although jurisdictions within the area affected by WNS changed status to vulnerable or endangered in the last year, or are conducting a review because of WNS.

TECHNICAL SUMMARY - Little Brown Myotis

Myotis lucifugus
Little Brown Myotis — Petite chauve-souris brune

Range of occurrence in Canada: Yukon, Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Demographic Information

Generation time *Calculated as a range derived from two methods (median age of breeding and mean age of cohort breeding).*	5-10 years (est.)
Is there an observed continuing decline in number of mature individuals? *WNS is predicted to expand north and west with expectations of continued population declines within WNS range.*	Yes
Estimated percent of continuing decline in total number of mature individuals within two generations (10-20 yrs). *Continued declines within WNS range expected. Remainder of range infected within 12-18 years, based on rate of spread, to date. Mortality predicted to be consistent across range.*	Unknown, but likely to exceed 75%
Inferred percent reduction in total number of mature individuals over the last three generations (15-30 yrs). *92% of known winter population in ON, QC, NB, NS declined by 94% within one generation, which implies >50% decline of the overall Canadian population. However, proportion of population occurring in west and north (within range as yet unaffected by WNS) is unknown.*	Unknown
Projected percent reduction in total number of mature individuals over the next three generations (15-30 yrs). *Continued declines within WNS range are expected. Remainder of range infected within 12-18 years, based on rate of spread to date and assumption that mortality is consistent across range.*	Unknown, but likely to exceed 90%
Estimated percent reduction in total number of mature individuals over three generations, over a time period including both the past and the future. *Declines of 94% over <1 generation in eastern range with expectation of similar declines westward and northward as WNS expands across range within next two generations.*	Unknown, but likely to exceed 90%
Are the causes of the decline clearly reversible and understood and ceased? *WNS is cause of mortality and there is no treatment at this time. It is expected to continue; spores persist in cave environments.*	Understood, but not ceased, nor reversible (at this time)

Are there extreme fluctuations in number of mature individuals? *Variation in individual hibernacula recorded but extreme fluctuations not evident for any known populations.*	Unknown, but not likely

Extent and Occupancy Information

Estimated extent of occurrence. *Newfoundland to British Columbia, north to Yukon and NT, edge of range in Nunavut*	EO: Not calculated, but well over 20,000 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value). *Hibernacula and maternity roosts historically reused at specific locations but most sites not known and summer foraging is over entire range.*	IAO: Not calculated, but well over 2,000 km^2
Is the total population severely fragmented? *Range is contiguous (with possible exception of Newfoundland and Pacific coast islands).*	No
Number of locations∗ *Use of WNS to define locations difficult to apply because < 50% of Canadian range impacted by WNS, to date.*	NA
Is there an observed continuing decline in extent of occurrence?	No, populations declining. EO still appears stable
Is there an observed continuing decline in index of area of occupancy? *If AO refers to hibernacula, most hibernacula likely will become population sinks because fungal spores persist.*	Unknown
Is there an observed continuing decline in number of populations? *Mainland populations may be a single population; spread of WNS suggests extensive mixing occurs in eastern North America but extent of east-west movement unknown.*	No; mainland populations may be single population. Island populations may be isolated but declines not recorded to date.
Is there an observed continuing decline in number of locations*?	NA; see *Number of Locations* above
Is there an observed continuing decline in area of habitat? *Hibernacula are habitats critical for population sustainability and population declines have been recorded in most hibernacula within WNS range. The hibernacula themselves persist and still serve as habitat in the structural sense but contamination is likely to persist as fungus is believed to remain as spores on the walls and in soil, for unknown length of time. This could indicate habitat decline because sites turn into population sinks due to the disease.*	Possibly
Are there extreme fluctuations in number of populations?	No

∗ See Definitions and Abbreviations on COSEWIC website, IUCN 2010 for more information on this term.

Are there extreme fluctuations in number of locations∗?	NA; see *Number of Locations* above
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals (estimated minimum)**
Unknown, considered common across its range in Canada, but may be less abundant in western and northern Canada. Pre-WNS estimates of 6.5 million in northeastern US (Frick *et al.* 2010a) also suggest that Canada's population would exceed one million.	
Total	Unknown, but likely to exceed one million

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or five generations, or 10% within 100 years]. *Model predictions for* Myotis lucifugus *in northeastern US predict 99% probability of functional extirpation by 2026. If WNS spreads at current rate (range: 200-250 km/yr), it could occur across Canada within 12-18 years*, *which is within the range of three generations (15-30 yrs).*	Probability of extinction is 99% in northeastern US, but it is not possible to extrapolate these results to the range in Canada due to incomplete survey data.

Threats (actual or imminent, to populations or habitats)

White-nose Syndrome is caused by a fungal pathogen (*Pseudogymnoascus destructans*), which likely arrived from Europe and was first recorded in the US in 2006 and in Canada in 2010. Population declines of >90% in the northeastern US and 94% decline in total known population of *Myotis* bats (*Myotis lucifugus*, *M. septentrionalis*) in hibernacula in Ontario, Quebec, NB, and NS. Data from summer are limited but indicate the same trend. Mixing of bats during autumn swarming events and transmission by people may spread WNS across species' range. Rate of spread has averaged 200-250 km/yr, to date. Predicted infection of entire Canadian range in 12-18 years. Other threats include wind turbines, colony eradication due to public concerns regarding disease transmission and other conflicts, and other disturbances.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Under review in US for Endangered Species status	
Is immigration known or possible? Myotis lucifugus *are mobile and some individuals undertake movements of 500-800 km between seasons and hibernacula.*	Likely
Would immigrants be adapted to survive in Canada? *Climate and food sources are similar to US conditions but immigrants might not be adapted to Pd.*	Yes/No

Is there sufficient habitat for immigrants in Canada? *Roosts and food are not thought to be limiting but hibernacula infected with Pd would become population sinks.*	No
Is rescue from outside populations likely? *Except for a population in Alaska, populations only exist south of Canada and they have been near extirpated in northeastern US states; western range likely to be infected. Also, any immigrants will likely be at risk from contaminated hibernacula.*	No

Status History

COSEWIC: Designated Endangered in an emergency assessment on February 3, 2012. Status re-examined and confirmed in November 2013.

Author of Technical Summary: Graham Forbes and Justina Ray

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric code**: A3be+4abe
Reasons for designation: Approximately 50% of the global range of this small bat is found in Canada. Subpopulations in the eastern part of the range have been devastated by White-nose Syndrome, a fungal disease caused by an introduced pathogen. This disease was first detected in Canada in 2010, and to date has caused a 94% overall decline in known numbers of hibernating *Myotis* bats in Nova Scotia, New Brunswick, Ontario, and Quebec. The current range of White-nose Syndrome has been expanding at an average rate of 200-250 kilometres per year. At that rate, the entire Canadian population is likely to be affected within 12 to 18 years. There is no apparent containment of the northward or westward spread of the pathogen, and proper growing conditions for it exist throughout the remaining range.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A3be because there is a suspected reduction in the total number of mature individuals of more than 50% in the next three generations (15-30 years) based on predicted infection rates of the remaining Canadian range within 12-18 years at similar mortality levels as recorded in the eastern range (94% decline in known winter hibernacula population in Ontario to NS). Also, due to the continued spread to sites within the infected range, no apparent containment of spread of *Pd* northward and westward, and optimal growing conditions for *Pd* in most of the remaining range and based on sub-criterion b (percent change in abundance in winter hibernacula and summer maternity colonies, and some summer acoustic survey) and sub-criterion e (*Pd* is an introduced pathogen likely from Europe, first recorded in 2006 and spread has been documented). Meets Endangered A4abe because there is a suspected and inferred reduction in the total number of mature individuals of greater than 50% within a 3-generation period in the past and into the future, where the reduction and its causes have not ceased. Sub-criteria b and e apply for same reasons as under A3, and sub-criterion a applies due to direct counts of infected and dead bats in hibernacula. Sub-criteria c and d do not apply for both A3 and A4 despite habitat declines that have likely occurred with *Pd* infection of hibernacula because the quantification of habitat decline was not used to infer population declines (sub-criterion c) and because this species is not exploited (sub-criterion a). A1 is not applicable because the causes of the decline have not ceased. A2 is not applicable because the proportion of the reduction in the overall Canadian population in the last generation affected by WNS is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Both the EO and IAO exceed the threshold for this criterion.

Criterion C (Small and Declining Number of Mature Individuals): Not applicable; total number of *Myotis lucifugus* unknown but certain to exceed 10,000 mature individuals.
Criterion D (Very Small or Restricted Population): Not applicable. The total number of mature individuals is unknown but greater than 1,000 and the number of locations likely exceeds the threshold.
Criterion E (Quantitative Analysis): Not applicable. Population viability model predicts probability of extinction at 99% by 2026 (13 years) in northeastern US, but not possible to extrapolate these results to the rest of the range in Canada because this population model is based on pre-WNS population dynamics of bats in the northeastern US, and there are no available data on population dynamics of western bats in Canada.

TECHNICAL SUMMARY - Northern Myotis

Myotis septentrionalis
Northern Myotis Chauve-souris nordique

Range of occurrence in Canada: Yukon, Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Demographic Information

Generation time. *Calculated as range derived from two methods (median age of breeding and mean age of cohort breeding).*	5-10 years (est.)
Is there an observed continuing decline in number of mature individuals? *Mortality events, population declines, and/or new infected locations occurred in winter 2012-13 in ON, QC, NB, NS. WNS is predicted to expand north and west with expectations of continued population declines within WNS range.*	Yes
Estimated percent of continuing decline in total number of mature individuals within two generations (10-20 yrs). *Continued declines within WNS range expected. Remainder of range infected within 12-15 years, based on rate of spread, to date. Mortality assumed to be consistent across range.*	Unknown, but likely to exceed 90%
Inferred percent reduction in total number of mature individuals over the last three generations (15-30 yrs). *92% of known winter population (ON, QC, NB, NS) declined by 94% within one generation, which implies >50% decline of the overall Canadian population. However, proportion of population occurring in west and north (within range as yet unaffected by WNS) is unknown.*	Unknown
Projected percent reduction in total number of mature individuals over the next three generations (15-30 yrs). *Continued declines within WNS range are expected. Remainder of range infected within 12-15 years, based on rate of spread to date, and assumption that mortality is consistent across range.*	Unknown, but likely to exceed 90%
Estimated percent reduction in total number of mature individuals over three generations (15-30 yrs), over a time period including both the past and the future. *Declines of 94% over one generation in eastern range with expectation of similar declines westward and northward as WNS expands across range within next two generations.*	Unknown, but likely to exceed 90%
Are the causes of the decline clearly reversible and understood and ceased? *WNS is cause of mortality and there is no treatment at this time. This threat is expected to continue; spores persist in cave environments.*	Understood, but not ceased, nor reversible (at this time)

Are there extreme fluctuations in number of mature individuals? *Variation in individual hibernacula recorded but extreme fluctuations not evident for any known populations.*	Unknown, but not likely

Extent and Occupancy Information

Estimated extent of occurrence. *Newfoundland to British Columbia, north to Yukon and NT.*	EO: Not calculated, but well over 20,000 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value). *Hibernacula and maternity roosts historically reused at specific locations but most sites not known and summer foraging is over entire range.*	IAO: Not calculated, but well over 2,000 km^2
Is the total population severely fragmented? *Range is contiguous (with possible exception of Vancouver Island and Newfoundland).*	No
Number of locations∗ *Use of WNS to define locations difficult to apply because < 50% of Canadian range impacted by WNS, to date.*	NA
Is there an observed continuing decline in extent of occurrence?	No, populations declining but EO still appears stable
Is there an observed continuing decline in index of area of occupancy? *If AO refers to hibernacula, most hibernacula likely will become population sinks because fungal spores persist.*	Unknown
Is there an observed continuing decline in number of populations? *Bats on mainland may be a single population; spread of WNS suggests extensive mixing in eastern North America but extent of east-west movement unknown.*	No; mainland populations may be single population. Island populations may be isolated but declines not recorded to date.
Is there an observed continuing decline in number of locations*?	NA; see *Number of Locations* above
Is there an observed continuing decline in area of habitat? *Hibernacula are habitats critical for population sustainability and population declines have been recorded in most hibernacula within WNS range. The hibernacula themselves persist and still serve as habitat in the structural sense but contamination is likely to persist as fungus is believed to remain as spores on the walls and in soil, for unknown length of time. This could indicate habitat decline because sites turn into population sinks due to the disease.*	Possibly

∗ See Definitions and Abbreviations on COSEWIC website, IUCN 2010 for more information on this term.

Are there extreme fluctuations in number of populations? *Number of subpopulations unknown but very low numbers expected to persist across range.*	No
Are there extreme fluctuations in number of locations∗?	NA; see *Number of Locations* above
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals (estimated minimum)
Unknown, considered common in central-eastern Canada, less abundant westward. Overall, proportion of captures attributable to this species during the summer and at swarming sites suggests *Myotis septentrionalis* is less abundant than *M. lucifugus*.	
Total	Unknown, but likely to exceed one million

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or five generations, or 10% within 100 years]. Myotis septentrionalis *is similar to* M. lucifugus *in body size, fecundity, lifespan, and vulnerability to WNS. Model predictions in northeastern US for* M. lucifugus *predict 99% probability of functional extinction by 2026. If WNS spreads at current rate (range 200-250 km/yr), it could reach the western/northwestern edge of their range in 12-15 years, which is within two generations (10-20 yrs).*	Not done. Results from *Myotis lucifugus* (99% probability of extinction in northeastern US) likely applies to *M. septentrionalis*. However, it is not possible to extrapolate these results to the rest of the Canadian range due to incomplete survey data.

Threats (actual or imminent, to populations or habitats)

White-nose Syndrome is caused by a fungal pathogen (*Pseudogymnoascus destructans*) that likely arrived from Europe and was first recorded in US in 2006 and in Canada in 2010. Population declines of >90% in northeastern US and 94% decline in total known population of *Myotis* bats (*Myotis lucifugus*, *M. septentrionalis*) in hibernacula in Ontario, Quebec, NB, and NS. Mixing of bats during autumn swarming events, and transmission by people, may spread WNS across the species' range. Rate of spread averages 200-250 km/yr, to date. Predicted infection of entire Canadian range in 12-15 years. Other threats include wind turbines, colony eradication due to public concerns regarding disease transmission and other conflicts, and other disturbances.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Placed on US Endangered Species List, Oct. 2013	
Is immigration known or possible? *Species is mobile and some undertake movements of at least 200-300 km between seasons and hibernacula.*	Likely

Would immigrants be adapted to survive in Canada? *Climate and food sources are similar to US conditions but any immigrants in near future would not be adapted to Pd.*	Yes/No
Is there sufficient habitat for immigrants in Canada? *Roosts and food are not thought to be limiting but hibernacula infected with Pd would become population sinks.*	No
Is rescue from outside populations likely? *Populations only exist south of Canada and they have been near extirpated in northeastern US states; western range is likely to be infected. Also, any immigrants will likely be at risk from contaminated hibernacula.*	No

Status History

COSEWIC: Designated Endangered in an emergency assessment on February 3, 2012. Status re-examined and confirmed in November 2013.

Author of Technical Summary: Graham Forbes and Justina Ray

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric code**: A3be+4abe
Reasons for designation: Approximately 40% of the global range of this northern bat is in Canada. Subpopulations in the eastern part of the range have been devastated by White-nose Syndrome, a fungal disease caused by an introduced pathogen. This disease was first detected in Canada in 2010 and to date has caused a 94% overall decline in numbers of known hibernating *Myotis* bats in Nova Scotia, New Brunswick, Ontario, and Quebec hibernacula compared with earlier counts before the disease struck. Models in the northeastern United States for Little Brown Myotis predict a 99% probability of functional extirpation by 2026. Given similar life history characteristics, these results are likely applicable to this species. In addition to its tendency to occur in relatively low abundance levels in hibernacula, there is some indication this species is experiencing greater declines than other species since the onset of White-nose Syndrome. The current range of White-nose Syndrome overlaps with approximately one third of this species' range and is expanding at an average rate of 200 to 250 kilometres per year. At that rate, the entire Canadian population will likely be affected within 12 to18 years. There is no apparent containment of the northward or westward spread of the pathogen, and proper growing conditions for it exist throughout the remaining range.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A3be because there is a suspected reduction in the total number of mature individuals of more than 50% in the next three generations (15-30 years) based on predicted infection rates of the remaining Canadian range within 12-18 years at similar mortality levels as recorded in the eastern range (94% decline in known winter hibernacula population in Ontario to NS). Also, due to the continued spread to sites within the infected range, no apparent containment of spread of *Pd* northward and westward, and optimal growing conditions for *Pd* in most of the remaining range and based on sub-criterion b (percent change in abundance in winter hibernacula and summer maternity colonies, and some summer acoustic survey) and sub-criterion e (*Pd* is an introduced pathogen likely from Europe, first recorded in 2006 and spread has been documented). Meets Endangered A4abe because there is a suspected and inferred reduction in the total number of mature individuals of greater than 50% within a 3-generation period in the past and into the future, where the reduction and its causes have not ceased. Sub-criteria b and e apply for same reasons as under A3, and sub-criterion a applies due to direct counts of infected and dead bats in hibernacula. Sub-criteria c and d do not apply for both A3 and A4 despite habitat declines that have likely occurred with *Pd* infection of hibernacula because the quantification of habitat decline was not used to infer population declines (sub-criterion c) and because this species is not exploited (sub-criterion a). A1 is not applicable because the causes of decline have not ceased. A2 is not applicable because the proportion of the reduction in the overall Canadian population in the last generation affected by WNS is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Both the EO and IAO exceed the threshold for this criterion.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. The total number of mature individuals is unknown but certain to exceed 10,000.
Criterion D (Very Small or Restricted Population): Not applicable. The total number of mature individuals is unknown but greater than 1,000 and the number of locations likely exceeds the threshold.
Criterion E (Quantitative Analysis): Not applicable. Population viability model predicts probability of extinction at 99% by 2026 (13 years) in the northeastern US for *Myotis lucifugus*. Although these results may apply to this species given similar life history characteristics and vulnerability to WNS, but not possible to extrapolate to the rest of the range in Canada because this population model is based on pre-WNS population dynamics of bats in the northeastern US, and there are no available data on population dynamics of western bats.

TECHNICAL SUMMARY - Tri-colored Bat

Perimyotis subflavus
Tri-colored Bat   Pipistrelle de l'Est
Range of occurrence in Canada: Ontario, Quebec, New Brunswick, Nova Scotia

Demographic Information

Generation time *Calculated as range derived from two methods (median age of breeding and mean age of cohort breeding).*	5-7 years (est.)
Is there an observed continuing decline in number of mature individuals? *Mortality events, population declines, and/or new infected locations occurred in winter 2012-13 in NB, NS, and presumably elsewhere. Expectation of continued decline within WNS range.*	Yes
Estimated percent of continuing decline in total number of mature individuals within two generations (10-14 yrs). *Canadian range is within WNS range and declines predicted to continue as WNS infects remaining hibernacula.*	Unknown, but likely to exceed 75%
Inferred percent reduction in total number of mature individuals over the last three generations (15-21 yrs). *Total declines of 94% (QC) and 75% (NB) recorded in eastern hibernacula; presumably occurring at same levels in parts of range where they are not monitored.*	Unknown, but likely to exceed 75%
Projected percent reduction in total number of mature individuals over the next three generations (15-21 yrs). *Catastrophic declines have already occurred and are predicted to continue as WNS infects remaining hibernacula.*	Unknown, but likely to exceed 90%
Estimated percent reduction in total number of mature individuals over three generations, over a time period including both the past and the future.	Unknown, but likely to exceed 75%
Are the causes of the decline clearly reversible and understood and ceased? *WNS is cause of mortality but without remedy it is expected to continue; spores persist in cave environments.*	Understood, but not ceased, nor reversible (at this time)
Are there extreme fluctuations in number of mature individuals? *Variation in individual hibernacula recorded but extreme fluctuations not evident for any known populations.*	Unknown, but not likely

Extent and Occupancy Information

Estimated extent of occurrence. *Southern half of Ontario eastward to Nova Scotia*	EO: Not calculated, but well over 20,000 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value). *Hibernacula and maternity roosts historically reuse specific locations but number unknown and summer foraging is over entire range.*	IAO: Not calculated, but well over 2,000 km^2
Is the total population severely fragmented? *Nova Scotia population may be isolated from remainder, but likely not severely.*	Unlikely
Number of locations∗ *Canadian population exists as one location, based on WNS as a threatening event occurring throughout the bat's Canadian range over short period of time.*	1
Is there an observed continuing decline in extent of occurrence?	No, populations declining but EO appears stable for now
Is there an observed continuing decline in index of area of occupancy? *If AO refers to hibernacula, some hibernacula likely will become mortality sinks because fungal spores persist.*	Unknown
Is there an observed continuing decline in number of populations? *Number of populations not known; NS bats may be a separate subpopulation but amount of movement between remaining subpopulation(s) in Ontario-New Brunswick is unknown.*	Unknown number of subpopulations
Is there an observed continuing decline in number of locations*? *Canadian population exists as one location and very low numbers expected to persist.*	No
Is there an observed continuing decline in area of habitat? *Hibernacula are habitats critical for population sustainability and population declines have been recorded in most hibernacula within WNS range. The hibernacula themselves persist and still serve as habitat in the structural sense but contamination is likely to persist as fungus is believed to remain as spores on the walls and in soil, for unknown length of time. This could indicate habitat decline because sites turn into population sinks due to the disease.*	Possibly
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗? *Canadian population exists as one location.*	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

∗ See Definitions and Abbreviations on COSEWIC website, IUCN 2010 for more information on this term.

Number of Mature Individuals (in each population)

Population	**N Mature Individuals (estimated minimum)**
Unknown, considered rare in Quebec, NB, and NS and rare-uncommon in parts of Ontario. Low numbers recorded in hibernacula throughout species' range. Estimate of 1,000-2,000 females in NS.	
Total	Unknown; <20,000 (?)

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or five generations, or 10% within 100 years]. *The results from* Myotis lucifugus *models (see above) suggest high probability of functional extirpation but* Perimyotis subflavus *have higher fecundity and model may not apply.*	Not conducted

Threats (actual or imminent, to populations or habitats)

White-nose Syndrome is caused by a fungal pathogen (*Pseudogymnoascus destructans*) likely from Europe that was first recorded in North America in 2006 and in Canada in 2010. Mortality of *Perimyotis subflavus* in infected hibernacula averages 76% in northeastern United States after several years of exposure. Estimated declines in hibernacula are 75% (NB) and 94% (Quebec). Autumn mixing of bats results in likely spread to all hibernacula. Other threats include colony eradication due to public concerns regarding disease transmission and other conflicts, and other disturbances.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Under review in US for Endangered Species status	
Is immigration known or possible? *Perimyotis subflavus are mobile and undertake significant movement between seasons and hibernacula.*	Likely
Would immigrants be adapted to survive in Canada? *Climate and food sources are similar to US conditions but any immigrants would not be adapted to Pd.*	Yes/No
Is there sufficient habitat for immigrants in Canada? *Roosts and food are thought to be not limiting but hibernacula infected with Pd would become population sinks.*	No
Is rescue from outside populations likely? *Populations only exist south of Canada and they have been near extirpated in the northeastern US.*	No

Status History

COSEWIC: Designated Endangered in an emergency assessment on February 3, 2012. Status re-examined and confirmed in November 2013.

Author of Technical Summary: Graham Forbes and Justina Ray

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric code**: A2abe+3be+4abe
Reasons for designation: This bat is one of the smallest bats in eastern North America. Approximately 10% of its global range is in Canada, and it is considered rare in much of its Canadian range. Declines of more than 75% have occurred in the known hibernating populations in Quebec and New Brunswick due to White-nose Syndrome. This fungal disease, caused by an invasive pathogen, was first detected in Canada in 2010, and has caused similar declines in Little Brown Myotis and Northern Myotis in eastern Canada and the northeastern United States. Most of the Canadian range of the species overlaps with the current White-nose Syndrome range, and further declines are expected as more hibernacula continue to become infected.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2abe because there is an observed reduction of greater than 50% in the total number of mature individuals over the last 3 generations where the causes have not ceased and based on sub-criteria a (direct counts of infected and dead bats in hibernacula), b (percent change in abundance in winter hibernacula and summer maternity colonies, and some summer acoustic survey) and e (*Pd* is an introduced pathogen likely from Europe, first recorded in 2006 and spread has been documented). 75% and 94% declines in hibernacula populations in New Brunswick and Quebec between 2010 and 2013 with an almost complete overlap between WNS and this species range in Canada suggest strongly that the population has already experienced over 50% decline. Meets Endangered A3be because there is a projected and suspected reduction in the total number of mature individuals of more than 50% in the next three generations (15-21 years) based on continued impact in infected hibernacula, and new infection of remaining hibernacula within Canadian range within 12-15 years at similar mortality levels as recorded to date (see above), and in the northeastern US. Sub-criteria b and e apply for same reasons as under A2. Meets Endangered A4abe because there is a suspected and inferred reduction in the total number of mature individuals of greater than 50% within a 3-generation period in the past and into the future, where the reduction and its causes have not ceased. Sub-criteria a, b and e apply for same reasons as under A2. Sub-criteria c and d do not apply for both A2, A3 and A4 despite habitat declines that have likely occurred with *Pd* infection of hibernacula since the quantification of habitat decline was not used to infer population declines (sub-criterion c) and since this species is not exploited (sub-criterion d). Sub-criterion (a) is not a sub-criterion applicable to A3. A1 is not applicable because the causes of declines have not ceased.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Both the EO and IAO exceed the threshold for this criterion.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Although 95% of all mature individuals are in a single Canadian population and there is a continuing decline, the total number of mature individuals is unknown and likely greater than 10,000 individuals.
Criterion D (Very Small or Restricted Population): Meets Threatened D2 since there are fewer than 5 locations and since WNS appears to be a single threatening event that is causing population declines over the entire range of this species in Canada within a short period of time. D1 does not apply since the total number of mature individuals is unknown but certain to exceed 1,000.
Criterion E (Quantitative Analysis): Not applicable.

PREFACE

In October 2011, the Province of Nova Scotia requested an emergency assessment on three species of bat, Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*M. septentrionalis*), and Tri-colored Bat (*Perimyotis subflavus*). The request was due to: concerns regarding the mortality levels from White-nose Syndrome (WNS) on various bat species in the northeastern United States since 2006; the apparent rate of spread of the disease; and its confirmation in NS, NB, Quebec, and Ontario. WNS is caused by a fungus, *Pseudogymnoascus destructans* (previously called *Geomyces destructans*, and hereafter referred to as *Pd*). In November 2011, the Chair of COSEWIC decided to proceed, and G. Forbes, the co-chair of the Terrestrial Mammals Subcommittee prepared a summary document with supporting evidence of the emergency condition. An Emergency Assessment Subcommittee met in February 2012 and made a recommendation to assign endangered status on an emergency basis to each species, which the Chair of COSEWIC communicated to the Minister of the Environment.

The rationale for the recommendation was: 1) catastrophic population declines have occurred in all three species in northeastern United States and similar impacts have occurred in Canada, with inference that future impacts to Canada will be same as had occurred in the United States; 2) a population model for *Myotis lucifugus* (considered applicable also to *M. septentrionalis* and *P. subflavus*), predicts functional extirpation (decrease to <1% of population) by 2026 for the northeastern region; and 3) predicted rate of spread was fast enough to impact >50% of the Canadian population within three generations. The criteria for designation for all three species were A3bce, A4bce, E.

As per COSEWIC policy, the three species were referred to the Terrestrial Mammals Subcommittee for immediate status report preparation and deliberation through the full COSEWIC process. The *Species at Risk Act* mandates the preparation of a full status report and a reassessment of the species within one year of an emergency listing decision by the Minister. At the time of COSEWIC's November 2013 assessment no such decision had been made. All three species are addressed here in a single status report because WNS was considered to be the dominant threat and it is common to all, and the biology of the species is sufficiently similar.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2013)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Little Brown Myotis
Myotis lucifugus

Northern Myotis
Myotis septentrionalis

Tri-colored Bat
Perimyotis subflavus

in Canada

2013

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Mammalia

Order: Chiroptera

Family: Vespertilionidae

Scientific name: *Myotis lucifugus* (LeConte 1831)

Scientific name: *Myotis septentrionalis* (Trouessart 1897)

Scientific name: *Perimyotis subflavus* (Cuvier 1832)

Common names:

For *M. lucifugus*: Little Brown Myotis or Little Brown Bat (English) and Petite chauve-souris brune (French). For *M. septentrionalis*: Northern Myotis, Northern Long-eared Myotis or Northern Long-eared Bat (English) and Chauve-souris nordique (French). For *P. subflavus*: Tri-colored Bat or Eastern Pipistrelle (English) and Pipistrelle de l'Est (French).

Myotis lucifugus has been recognized as a species for over a century. *M. septentrionalis* was formerly considered a subspecies of *M. keenii* (van Zyll de Jong 1979) but the two species have numerous morphological differences and their ranges do not overlap; *M. septentrionalis* is now recognized as a species (Wilson and Reeder 2005). *Perimyotis subflavus* was previously called *Pipistrellus subflavus* (Eastern Pipistrelle) but the genus and common name were changed based on taxonomic work that indicated that this taxon differed significantly from European pipistrelles, in both morphology and genotype (Hoofer *et al.* 2006).

Morphological Description

All three bat species (Figure 1) are small-bodied bats typical of the Vespertilionidae, the plain-nosed bats. External characteristics, with measurements from Canadian specimens (van Zyll de Jong 1985), are used here to describe the three species below:

Figure 1. Images of the three bat species; clockwise, from top left; *Myotis lucifugus* (dead bat with visual signs of WNS on muzzle ears and wings; Berryton Cave, NB); *M. septentrionalis* (with visual signs of WNS on forearm; Lake Charlotte, NS); *Perimyotis subflavus* (Hayes Cave, NS). Note the elongated ears and pointed tragus typical of *M. septentrionalis*. (Photo credits: *M. lucifugus*: K. Vanderwolf; *M. septentrionalis* and *P. subflavus*: H. Broders.)

Myotis lucifugus:

A small to medium-sized (Avg. mass 7.9 g; range 5.5-11.0 g; wingspan 22-27 cm) brown-pelaged bat. The tragus is short and blunt (Fenton and Barclay 1980; van Zyll de Jong 1985).

Myotis septentrionalis:

This species is very similar in colour and size (Avg. mass 7.4 g; range 4.3-10.8 g; wingspan 23-26 cm) to *M. lucifugus* but distinguished by their long, slender, and pointed tragus, and ears that extend beyond the nose when pressed forward (van Zyll de Jong 1985; Caceres and Barclay 2000).

Perimyotis subflavus:

A small bat (Avg. mass 6.9 g; range 6-7.9 g; wingspan 20-26 cm) identifiable, as adults, by distinctive tri-coloured hairs.

Population Structure and Variability

There is weak population genetic structure within *Myotis lucifugus* (Dixon 2011) and *M. septentrionalis* (Arnold 2007). The lack of strong structure likely is due to their vagility (*i.e.,* seasonal movements of several hundred km; see *Migration* section) and swarming behaviour in autumn, during which bats from a large area mix and mate (Fenton 1969). Any existing structure may result from females returning each year to the same maternity colonies where they were born (*i.e.,* natal philopatry). Analyses of microsatellite loci of female *M. septentrionalis* indicate local-scale population structuring, which suggests that dispersal is greater in males (Arnold 2007). Philopatry is not well understood because some females move between maternity colonies within and between years (Watt and Fenton 2008; Dixon 2011).

Perimyotis subflavus females also show philopatry to maternity colonies each year (Griffin 1934; Veilleux and Veilleux 2004) and presumably have similar population genetic structure as *M. lucifugus*. There are no published data on genetic structuring in *P. subflavus*.

Designatable Units

Myotis lucifugus:

The taxonomy of *Myotis lucifugus* in western Canada and the United States (US) is under debate. Four of six subspecies recognized by van Zyll de Jong (1985) are found in Canada. *Myotis l. lucifugus* is found from Newfoundland (NL) to British Columbia (BC) and eastern Yukon, while *M. l. alascensis* is found in BC and western Yukon (Lausen *et al*. 2008; T. Dewey and B. Slough, unpub. data). *M. l. carissima* is in the Okanagan region of BC, and *M. l. pernox* in the Rocky Mountains. The subspecies designations are based on size (mainly forearm length) and pelage colour. More recent analyses based on genetics have led to a debate ranging from whether *M. lucifugus* in western Canada are actually separate species or not even subspecies. Preliminary population genetic studies on *M. lucifugus* on either side of the Rocky Mountain Continental Divide suggested evidence of genetic structuring (Russel *et al*. 2012) supporting some morphological differentiation (*i.e*., significant forearm differences east vs west of Rocky Mountains; C. Lausen unpub. data). Analyses using mtDNA suggested that the four western subspecies may be separate species (Carstens and Dewey 2010; Dewey 2006). The subspecies in BC and Alaska (*M. l. alascencis*) has been suggested as a separate species (ADFG 2013). However, Lausen *et al.* (2008) concluded that the validity of using mtDNA to determine subspecies of this group is problematic and, based on nuclear DNA analyses, determined that even the subspecific status for one (*M. l. carissima*) is invalid. Also, Lausen *et al*. (2008) question the validity of other subspecies because haplotypes of one subspecies (*M. l. lucifugus*) were found within the ranges of the other subspecies (Carstens and Dewey 2010; Dewey 2006). In addition, differences in pelage were not consistent to either putative subspecies.

In conclusion, differences in morphology and genotype somewhat exist in western *M. lucifugus* range, but it is unlikely that designatable units (DUs) can be applied for any species across their range because uniqueness and significance has not been established. The same situation applies in eastern Canada; genetic analyses of bats in Newfoundland and Labrador (NL) are underway, but not complete (B. Rodrigues, pers. comm.) and it is unknown if *M. lucifugus* (and *M. septentrionalis*) on NF are isolated and distinct. The distribution of *M. lucifugus* in Canada is continuous (with the possible exception of NF) and, in lieu of clarity on taxonomy in western Canada and NF, and a confirmation of uniqueness and significance, the report recognizes a single designatable unit.

Myotis septentrionalis:

Systematic research on *M. septentrionalis* is limited. No Canadian subspecies are recognized (van Zyll de Jong 1985). There are no apparent barriers to the movement of subpopulations in Canada. *M. septentrionalis* in Canada are considered to comprise a single designatable unit.

Perimyotis subflavus:

The Canadian population is assigned to *P. s. subflavus* (van Zyll de Jong 1985). There is a possibility that *P. subflavus* in NS are isolated from the rest of the population (Broders *et al.* 2003) and warrant subspecies status because of morphometric differences (Hunyh 2010, H. Broders, unpub. data) including larger average size (Poissant and Broders 2008). However, genetic analyses did not identify uniqueness (Hunyh 2010), although more work is required. Also, isolation has not been confirmed. A single designatable unit is proposed for use in this report.

Special Significance

The public have both negative and positive attitudes towards bats. Negative attitudes relate to their secretive, nocturnal habits, and their association with diseases such as rabies and histoplasmosis. Bats are viewed positively because they consume insects, many of which are considered pests in the forestry, agriculture, and health sectors. Individual *Myotis lucifugus* each consume 4-8 g of insects per night (Anthony and Kunz 1977; Kurta *et al.* 1989) and a decline of one million bats equates to a potential reduction in consumption of 660-1,320 metric tons annually (Boyles *et al.* 2011). The most recent estimate of a minimum decline of 5.7 million bats from White-nose Syndrome (WNS) (see **Population Sizes and Trends** and **Threats**) equates to reduction in consumption of 3,762-7,523 metric tons annually. A reduction in bats has been shown to result in increased populations of some insect species (Wilson and Barclay 2006; Kalka *et al*. 2008; Williams-Guillen *et al*. 2008). Given the small scale of inquiry of these studies, the relationship between bat and insect populations at a regional level is difficult to establish because the compensatory or additive response by insects to bat predation is unknown. If bat predation is the limiting factor in the insect population then removal of bats could increase insect populations.

The economic value of bats has been estimated based on the cost to farmers if they had to control insects not removed by bats. Based on work in Texas on the consumption of various agricultural pests by Mexican Free-tailed Bat (*Tadarida brasiliensis)*, the cost to farmers would approximate US$22.9 billion per year if all insect-eating bats were removed (Cleveland *et al.* 2006; Boyles *et al.* 2011). It is not known how well these data on *Tadarida* in Texas apply to smaller *Myotis* species in the northeast. The impact to the forestry industry is not known but numerous Lepidopteran pests are consumed by bats (e.g., spruce budworm, *Choristoneura* spp.) (Wilson and Barclay 2006) and decreases in wood production may occur with reduced levels of bat depredation. The impact to society and environment of increased pesticide use (e.g., water quality, health, conflict) would be an additional cost. The value of bats in suppressing mosquito-borne diseases (e.g., West Nile virus) is unknown.

DISTRIBUTION

Global Range

<u>*Myotis lucifugus:*</u>

This species is distributed over much of North America, including the Sierra Nevada range of Mexico, and into Alaska (Figure 2). They are rare to absent in much of Texas and Florida, and north of the treeline in Canada and Alaska (van Zyll de Jong 1985).

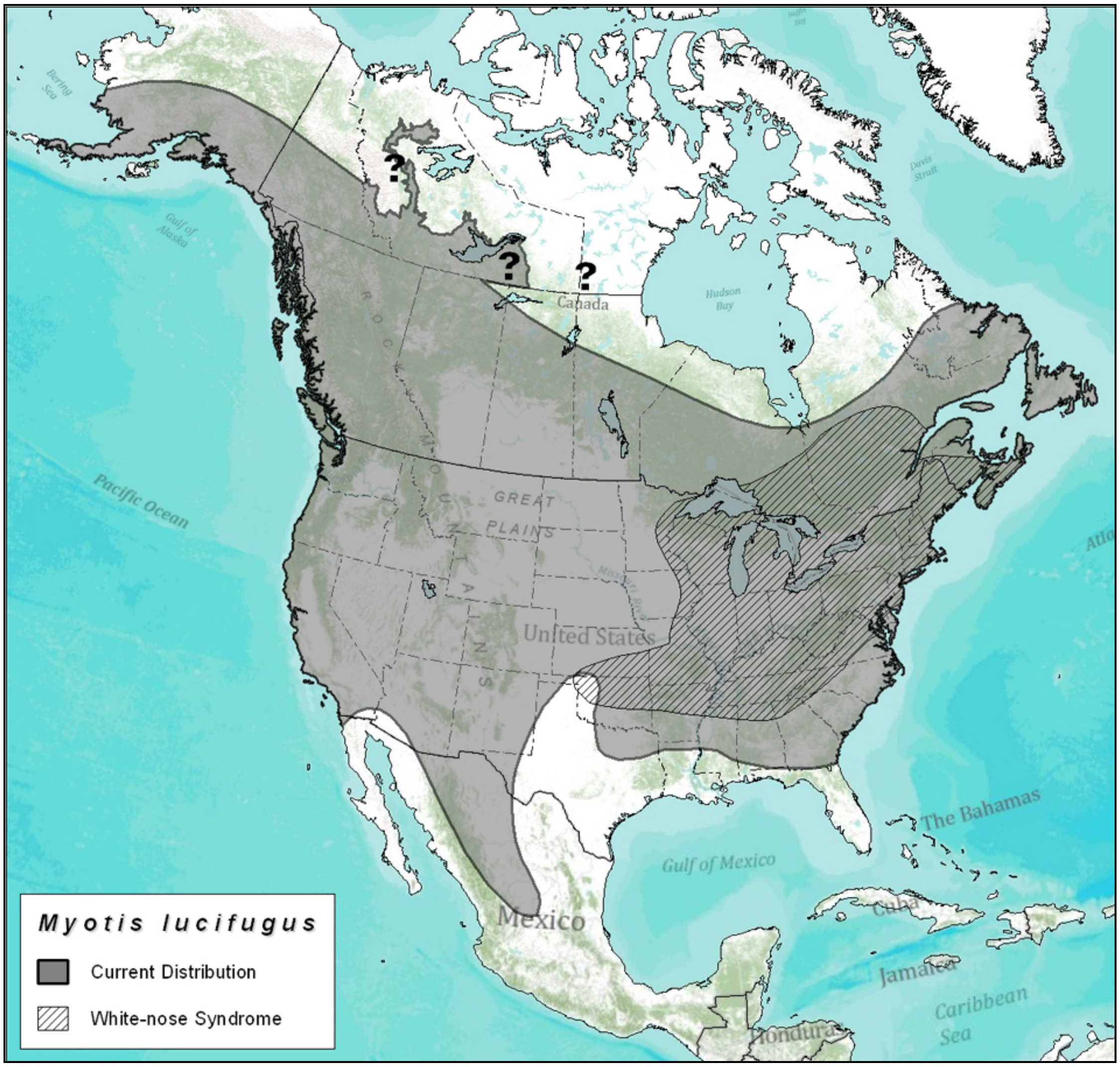

Figure 2. Approximate distribution of *Myotis lucifugus* and White-nose Syndrome, as of August 2013. See text for details on bat distribution; some records in NT and Nunavut (indicated with '?') are probable but unconfirmed, or may be extralimital. WNS map contains locations of confirmed *Pseudogymnoascus destructans* and clinical WNS characteristics (see Figure 5; National Wildlife Health Center 2013). (Map created by J. Wu, COSEWIC Secretariat.)

Myotis septentrionalis:

The range covers much of North America, although it is smaller than that of *M. lucifugus* and located more eastward, particularly in the US where the species is absent in the mid-western US (Figure 3). *M. septentrionalis* can be found in a few sites in the southeastern US (*i.e.*, Alabama, North Carolina) but is generally rare south of the Appalachian mountain range (van Zyll de Jong 1985). The species appears more common in northern parts of its range.

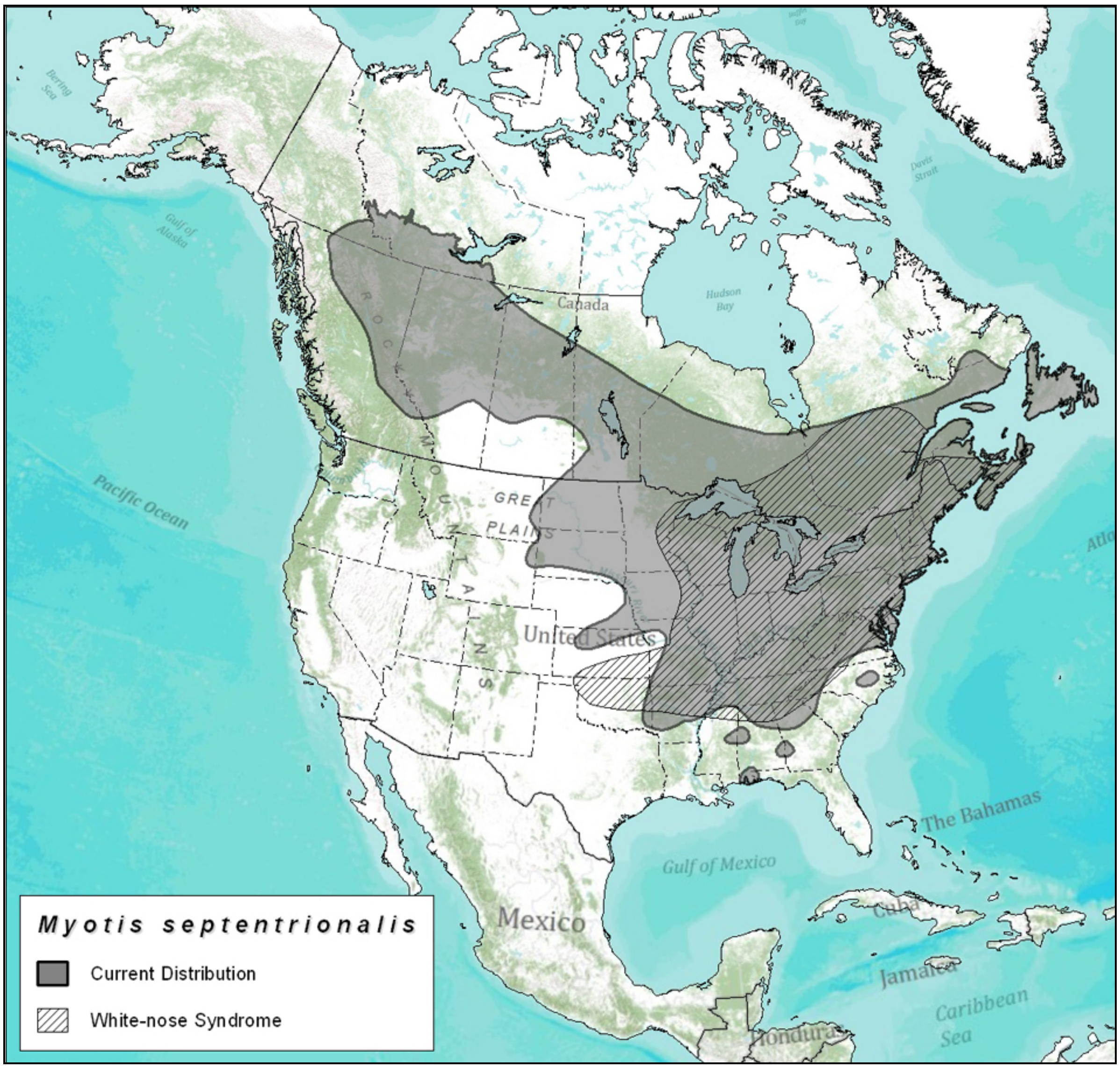

Figure 3. Approximate distribution of *Myotis septentrionalis* and White-nose Syndrome, as of August 2013. See text for details on bat distribution. WNS map contains locations of confirmed *Pseudogymnoascus destructans* and clinical WNS characteristics (see Figure 5; National Wildlife Health Center 2013). (Map created by J. Wu, COSEWIC Secretariat.)

Perimyotis subflavus:

P. subflavus is an eastern North American species that ranges from the Maritimes to the Great Lakes, and south to the eastern coast of Central America (van Zyll de Jong 1985; Figure 4). The species appears to be expanding its range westward into the US prairies, possibly by using new dams and mines for hibernacula (Geluso *et al.* 2004).

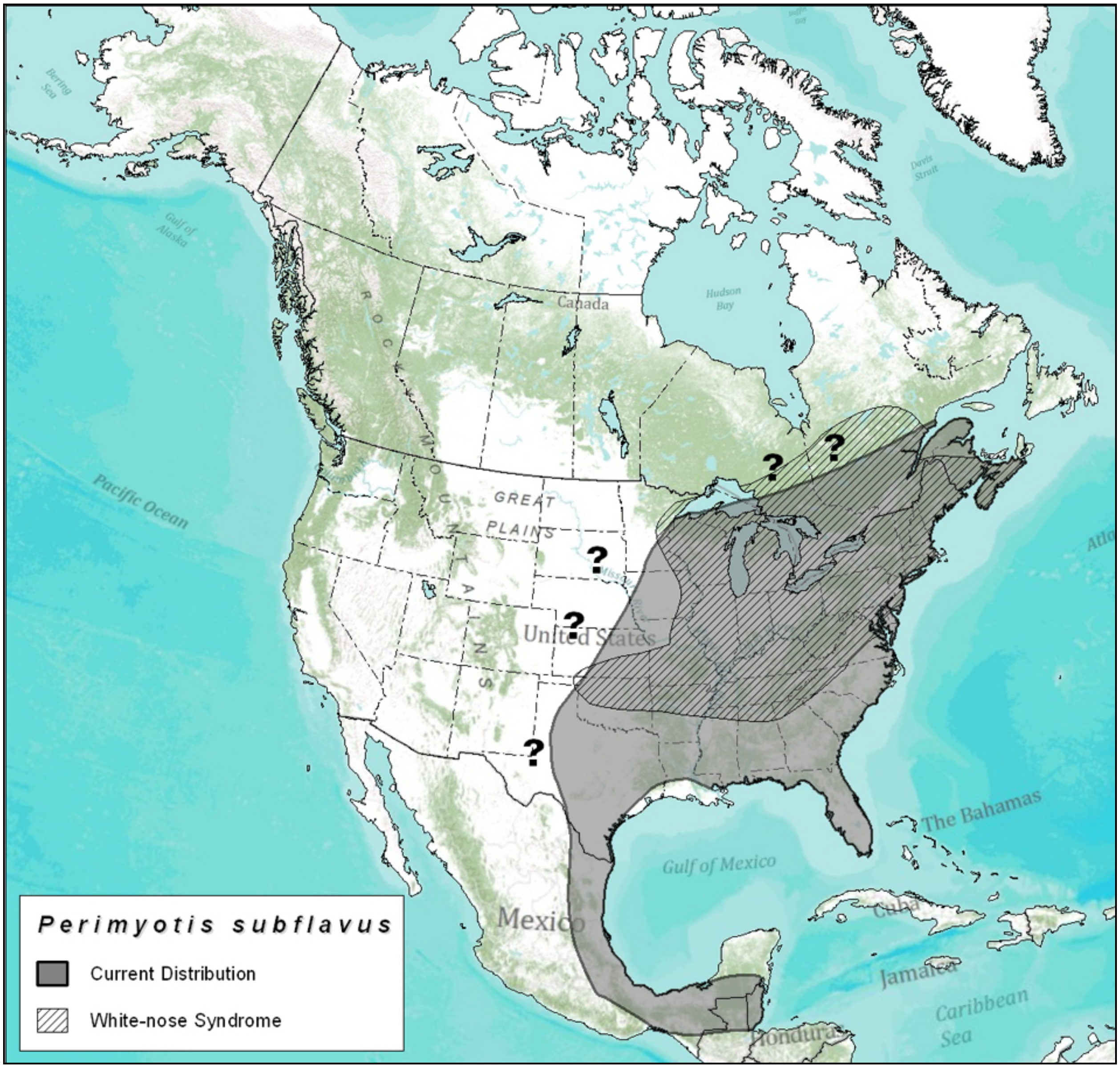

Figure 4. Approximate distribution of *Perimyotis subflavus* and White-nose syndrome, as of August 2013. See text for details on bat distribution. WNS map contains locations of confirmed *Pseudogymnoascus destructans* and clinical WNS characteristics (see Figure 5; National Wildlife Health Center 2013). Question marks indicate areas where status of *P. subflavus* is uncertain. (Map created by J. Wu, COSEWIC Secretariat.)

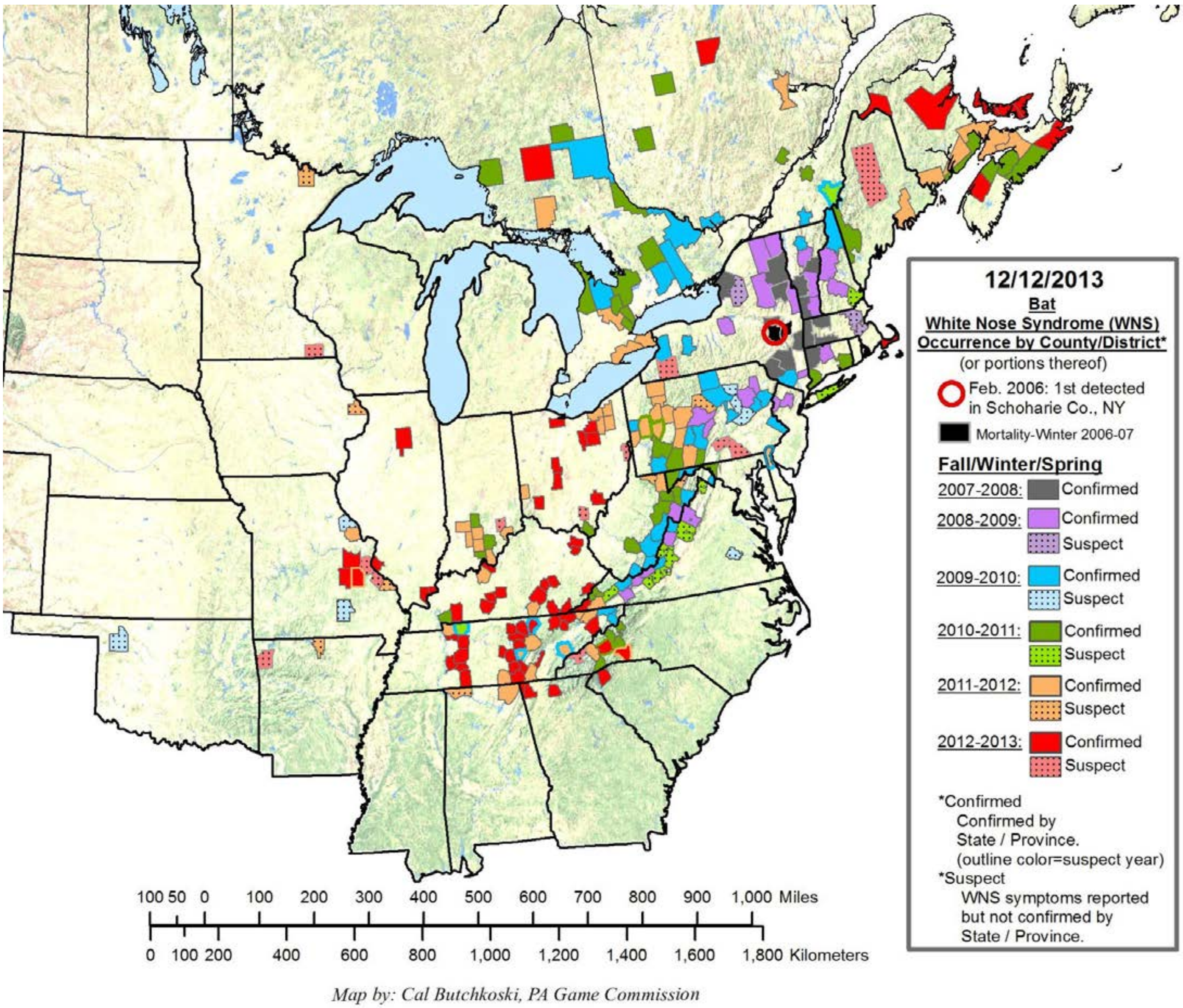

Figure 5. Location of confirmed and suspected cases of White-nose syndrome in North America, as of September 2013. Suspected cases are positive tests for *Pseudogymnoascus destructans* (*Pd*), confirmed cases are where mortality events have occurred. First record was in Albany, New York in February 2006 (coincides with circle on map key). A suspected case in Oklahoma is 2400km from epicentre. *Pd* was recorded in northeastern Minnesota near the Canadian border, in 2012. (Source: National Wildlife Health Center 2013.)

Canadian Range

Myotis lucifugus:

Approximately 50% of this species' global range is in Canada, and it occurs in every province and territory, with occasional records in southwestern Nunavut (Figure 2). It occurs throughout much of NF and south-central Labrador, and across Canada below tree-line to the Pacific Ocean, including Haida Gwaii and Vancouver Island (van Zyll de Jong 1985; Grindal *et al*. 2011; Burles *et al*. 2014). Its distribution at the northern range boundary is less defined because of less survey effort, the large expanse of land, and lack of knowledge of hibernacula location. *M. lucifugus* is found across the southern third of the NT and south of 64° in the Yukon (Slough and Jung 2007) but it is unknown whether they hibernate in the Yukon. Scattered records exist further north than the range shown in Figure 2, but it is unknown if these are extralimital records or residents (J. Wilson, pers. comm.). The most northerly hibernaculum known is in NT, between 60-61° latitude, and there is one suspected but not confirmed site near 65° (J. Wilson, pers. comm.).

Myotis septentrionalis:

Approximately 40% of this species' global range is in Canada. The species has been recorded from parts of Newfoundland westward and south of the treeline to the Yukon and northern BC (van Zyll de Jong 1985; Brown *et al.* 2007; Henderson *et al*. 2009; Park and Broders 2012; Broders *et al*. 2013; Reimer and Kaupas 2013) (Figure 3). It is absent from the Canadian prairies (Lausen 2009) but can be found on the western slopes of the Selkirk Mountains from Trout Lake, BC, northwards, and in the coastal mountains of northern BC (Caceres 1998; Lausen and Hill 2010). Breeding is confirmed in Yukon (Lausen *et al*. 2008) and NT (J. Reimer, unpub. data). *M. septentrionalis* appear to be common in the oil sands region (Grindal *et al*. 2011) and exist in southern parts of NT, west to the Liard River watershed of northern BC and southeastern Yukon. Overwintering has not been recorded in the Yukon (Jung *et al.* 2006; Slough and Jung 2007) but is likely in NT (J. Wilson, pers. comm.); *M. septentrionalis* have been captured mid-September flying into the single known hibernacula for *M. lucifugus* in southeastern NT (Lausen 2011).

Perimyotis subflavus:

Approximately 15% of this species' global range is in Canada. The range of *P. subflavus* in Canada is the smallest of the three species, with the species having been recorded only in southern parts of NS, NB, Quebec, and central Ontario, southward (van Zyll de Jong 1985; Fraser *et al*. 2012; Figure 4). Broders *et al.* (2003) suggested that the population in southeastern NS may be isolated. Breeding occurs in NS (H. Broders, pers. comm. 2012; Broders *et al.* 2003) but is uncertain for NB (Broders *et al.* 2001).

The extent of occurrence (EO) for the three species was not calculated because the range covers much of Canada for the *Myotis* spp., and from NS to the southern half of Ontario for *Perimyotis subflavus*; the EO for each species is well over 20,000 km^2, exceeding the relevant threshold for COSEWIC critieria. Index of area of occurrence (IAO) also was not calculated because the EO and IAO would essentially be the same area; these bat species forage widely over many habitats. It would have been informative to construct an IAO on just hibernacula because hibernacula likely are the most important spatial feature for survival; however, most hibernacula have not been mapped.

Search Effort

The distribution of bats in Canada was delineated from observational surveys using mist-netting and ultrasonic detectors that can detect echolocation calls. The search effort in more remote areas is limited but the general distribution and relative abundance of the species has been established across their range. Intensive fieldwork and research programs (*i.e.*, capture and echolocation surveys at multiple sites, banding, radio-tagging over multiple years) has been ongoing in parts of Quebec, Ontario, MB, and BC for over 40 years, and nearly as long in parts of the Prairies. Similar field research began in the 1990s in NB, NS, and the Yukon, and after 2000 in NL, PEI, and NT.

Monitoring of bat populations was localized before the arrival of WNS, mainly because species like *Myotis lucifugus* were considered ubiquitous and the other two species were not conservation priorities. Most summer surveys were conducted over small areas and for short periods of time and focused mainly on relative abundance and habitat use. Systematic surveys are lacking for most of the range.

The number and location of most hibernacula are unknown because hibernacula are difficult to locate. Caves and abandoned mines have the most potential as hibernacula but often are unsafe to enter to conduct winter hibernacula counts. Researchers may be able to establish use by documenting activity at the entrance during the fall swarming season and spring emergence, but equipment and staff required to monitor bats acoustically or trap and identify bats is not widely available. Caves and mines known to contain large numbers of bats occur in the Maritimes, southern Quebec, and Ontario, but more are being discovered (M. Elderkin, pers. comm.; Fenton 1970a; Mainguy *et al*. 2011; D. McAlpine and H. Broders, pers. comm. 2012; C. Willis, pers. comm.). No natural hibernacula are known in PEI (Henderson *et al*. 2009) and a single large (*i.e.*, 1,000 bats) and several small (*i.e*., <20 bats) are known in Newfoundland (S. Moores, pers. comm. 2012). Information on hibernacula in the northern parts of their range (e.g., Labrador and northern Quebec, westward) is very limited. New surveys have begun in various mines in Kirkland Lake, North Bay, and Algoma District of northcentral Ontario (P. Davis, pers. comm.). A number of sites between Wawa, Ontario and Winnipeg, Manitoba are known (Dubois and Monson 2007) but few hibernacula are recorded in much of the western range of *M. lucifugus* and *M. septentrionalis*. In Alberta, four hibernacula are known (Schowalter 1980; Lausen and

Barclay 2006, Hobson, pers. comm.). A single winter hibernaculum for *M. lucifugus* recently was discovered in southern NT (Lausen 2011) and no winter hibernacula have been recorded in the Yukon, to date (Jung *et al*. 2006).

In most jurisdictions, only a subset of the known hibernacula are surveyed. In Newfoundland, hibernacula have been monitored since 2009, with consistent methods at two hibernacula since 2011. The main known hibernacula in NS have been internally surveyed for the last several years (H. Broders, pers. comm.), and in NB all known hibernacula (n= 10) were internally surveyed in 2009/10 (before arrival of WNS) and annually since WNS arrived (D. McAlpine, pers. comm.). In Quebec, the entrances of three caves were externally monitored from 2002-2008 using automated 'beam-break' laser systems. Abundance counts were made inside an additional five hibernacula after WNS was detected in nearby New York. The monitoring of hibernacula increased to over 12 sites in 2009/10 but was discontinued for security issues and data exist for only 4-5 sites, at present. In southcentral Ontario, eight hibernacula were internally surveyed and five maternity colonies are being monitored (L. Hale, pers. comm.). An additional 51 sites from eastern Ontario to Wawa have been monitored with acoustic (n = 51) and capture (n = 13) surveys since the arrival of WNS (J. Bowman, pers. comm.). A total of 11-13 sites have been monitored in Manitoba since 1988 (Dubois and Monson 1987), and sites in northwestern Ontario were surveyed for presence of WNS during winter 2011/12 (Martinez *et al*. 2012). Cadomin Cave, the largest hibernaculum known in Alberta, has been surveyed periodically since the 1970s (Olson *et al.* 2011). In Ontario, the Craigmont site has been monitored for varying periods since 1946 (Keen and Hitchcock 1980).

Identification to species is generally reliable using captured individuals, at least east of the Canadian Rockies (see **Abundance**). In the last 20 years, ultrasonic detectors have been widely used to determine bat distribution and abundance. *Myotis* species are difficult to separate to species level using ultrasonic detectors (Brigham *et al*. 2002) and extra analyses are often required (e.g., Lausen and Barclay 2006; Broders *et al.* 2004). The greater richness of *Myotis* species (*i.e*., seven species in BC versus two species in the Maritimes; van Zyll de Jong 1985) potentially limits the effective use of bat detectors, particularly in western Canada.

Surveillance for the presence of *Pseudogymnoascus destructans* (*Pd*) (see **Threats**) began in southeastern Canada in 2009. In NS, public reporting of sightings and carcasses is coordinated using a dedicated government web page (M. Elderkin, pers. comm.). Agencies in Manitoba westward have recently prepared protocols for testing suspected cases of WNS. An inter-agency survey is coordinated by the Canadian Cooperative Wildlife Health Centre. From November 2012 - May 2013, 178 suspected WNS bats from five provinces (Ontario to NS) were submitted (CCWHC 2013). Similar efforts are underway in the US; 1,500 specimens of 24 bat species from 41 states and seven provinces had been tested as of summer 2012 by the US National Wildlife Health Center (Ballmann 2012).

HABITAT

Habitat Requirements

Habitat for bats is composed of: 1) hibernacula for overwinter survival and 2) summering areas with suitable foraging areas within commuting range to structures used for roosting or maternity colonies. The habitat requirements of temperate-region bats vary by season.

Maternity sites (trees, rock crevices, buildings, bat houses) and hibernacula (cave, mine, or building used for hibernation) are the main limiting habitat features for the three species within their range (Barclay and Brigham 1996; Norquay *et al*. 2013). Hibernation allows non-migratory, insect-eating bats to persist in a region when ambient temperature declines and insects are not available in winter. The physiological needs of the species (see **Physiology**) results in only specific sections of a site being useful as hibernacula. Although the recorded range for each species varies (*Myotis lucifugus*: -4 to 13°C, *M. septentrionalis*: 0.6 to 14°C, *Perimyotis subflavus*: 0 to 17.8°C, Webb *et al*. 1996), the sections used as hibernacula typically have a temperature range of 2-10°C (Fenton 1970a; Anderson and Robert 1971; McNab 1974; Vanderwolf *et al*. 2012). Small-bodied bats also use hibernacula with high humidity (>80%) levels. However, sites with running water can experience wide fluctuations in temperature and often are avoided. Numerous structural features influence temperature and humidity, such as number of openings, cave size, and length and angle of tunnels (Davis 1970; Raesly and Gates 1987). Not all sites with appropriate micro-habitat features are hibernacula; macro-habitat features, such as quality and quantity of autumn foraging habitat, may influence selection of a particular site (Raesly and Gates 1987).

None of the three species typically overwinters in buildings. Among the three species, *Myotis septentrionalis* may hibernate in cooler sections of a cave, compared to *M. lucifugus* (Barbour and Davis 1969). *Perimyotis subflavus* is considered to have the most rigid overwintering habitat requirements; they often roost in the deepest part of caves where temperature is the least variable, have the strongest correlation with humidity levels, and use warmer walls than other species (Fujita and Kunz 1984; Raesly and Gates 1987; Briggler and Prather 2003).

In spring, females of each species leave winter hibernacula and give birth and raise pups in maternity colonies. For *Myotis lucifugus*, the maternity colonies often exist in warm sites that facilitate pup growth rates, such as attics of buildings and under bridges, in rock crevices, or in cavities of canopy trees in forests (Fenton and Barclay 1980; Coleman and Barclay 2011).

Myotis septentrionalis rarely use human-made structures for roosting and are more strongly associated with the density and characteristics (e.g., height, diameter, age, decay class) of trees (Caceres and Barclay 2000; Jung *et al*. 2004; Broders and Forbes 2004; Henderson and Broders 2008; Henderson *et al.* 2008). Maternity colonies in NF, NS, and NB usually were in larger trees, ranging from 25 - 44 cm diameter at breast height (Broders and Forbes 2004; Garroway and Broders 2008; Park and Broders 2012). The location of a maternity colony is important because it may contain hundreds of females with young and be the only maternity site in a large area (Broders and Forbes 2004).

Males roost during daytime in a wide variety of structures, including buildings and bridges (mainly *M. lucifugus*), rock crevices, behind flaking bark, and within tree cavities, often at many different sites during the summer (Fenton and Barclay 1980; Caceres and Barclay 2000). *Myotis* species generally roost in tall, large-diameter snags that are in the early to middle stages of decay and located in open areas within mature-overmature forest (Jung *et al*. 2004).

Less is known about summer roosts of *P. subflavus*. In the US, females returned to same area (0.4 ha) each summer and used the same 4-6 trees per year, suggesting value in familiar (and possibly limited) structures (Veilleux and Veilleux 2004). Roosts can also be in dead clusters of leaves on trees (Veilleux *et al.* 2003). In NS, all 30 radio-tagged bats had day and maternity roosts in large clumps of arboreal lichens *(Usnea spp.*) that grow on coniferous or deciduous tree species; as many as 18 *P. subflavus* were found in a cluster (Poissant *et al.* 2010). In more modified landscapes, many maternity colonies are located in barns or similar human-made structures (Fujita and Kunz 1984).

Bat abundance in summer may be a function of available roost sites and prey, but information is lacking (Fenton 1997). For example, the minimum density of roost trees required to support bats in a stand has not been established. Insect availability in different forest types is difficult to quantify and it is unknown how much of the relative abundance of bats is due to differences in prey or roost availability, foraging conditions (*i.e*., wind, clutter), or predator avoidance. The interaction among these variables complicates the issue further. Small openings in the canopy, created either by gap dynamics or forest harvest, are used by foraging bats (Grindal and Brigham 1999; Jung *et al*. 1999; Patriquin and Barclay 2003). However, large-scale removal of canopy creates windy conditions, different prey abundance, and possibly an increased risk of predation (papers in Barclay and Brigham 1996; Grindal and Brigham 1999). Small *Myotis* bats generally avoid large areas of cleared land, such as farm fields (Henderson and Broders 2008), clearcuts (Hogberg *et al*. 2002), and large post-fire landscapes (Randall *et al*. 2011). Instead, they forage over still water (mainly *M. lucifugus*, *Perimyotis subflavus*), rivers (all three species), and in forest gaps, edges, or along trails (all three species, particularly *M. septentrionalis*) (Crampton and Barclay 1996; Jung *et al*. 1999; Holloway and Barclay 2000; Broders *et al*. 2003). Centres of clearcuts (>30 m from forest edge) in northern Alberta were used 2-2.5 times less than the edges of forest islands in clearcuts, or forest edges by *M. lucifugus* (Hogberg *et al*. 2002), and avoided completely by *M. septentrionalis* (Patriquin 2001). Natural roosts are located in forest and bats commute between roost and forage areas, often along waterways, forest edges, and above the canopy.

Both *Myotis* species have been captured in a wide range of deciduous and coniferous forest stands (*i.e*., Kunz 1973; Caire *et al*. 1979; Crampton and Barclay 1996; Henderson and Broders 2008). In a comparison of Trembling Aspen (*Populus tremuloides*), Aspen-Spruce (*Picea glauca*), and Jack Pine (*Pinus banksiana*) stands of the same age, only 2% of *M. lucifugus/M. septentrionalis* echolocation calls were recorded in Jack Pine stands, possibly because the less complex forest may have had lower prey abundance (Kalcounis *et al*. 1999). For *Perimyotis subflavus*, the effect of forest type likely is even less important because the species mainly forages over watercourses and streamside vegetation (Davis and Mumford 1962) and roosts in a range of tree species (*i.e., Quercus*, *Pinus, Picea*) found in adjacent forest (Perry and Thill 2007; Poissant *et al*. 2010).

Numerous bat species are more abundant in the oldest forest stands (e.g., ‘old growth’) and stand age appears to be more important than type of forest (Barclay and Brigham 1996). *Myotis lucifugus* and *M. septentrionalis* were more abundant in old versus young Aspen mixedwood forest of central Alberta (Crampton and Barclay 1996) and were detected 2.7-5.3 times more in old-growth White Pine (*Pinus strobus*) stands than in younger and harvested White Pine and boreal mixedwood stands in central Ontario (Jung *et al*. 1999). The use of old forest likely is related to increased snag availability for roosting (Crampton and Barclay 1996; Krusic *et al*. 1996) and ease of foraging under closed canopy (Jung *et al*. 1999). *M. septentrionalis* select sites with higher density of snags and large diameter trees (Sasse and Pekins 1996; Broders *et al*. 2005). Evidence of a reliance on older forest also has been shown for *Perimyotis subflavus* (Perry and Thill 2007; Farrow and Broders 2011).

Myotis lucifugus may be less vulnerable than the other species to clearing of forest land in southern parts of their range, possibly because *M. lucifugus* often have maternity roosts in buildings, and forage over water. In contrast, *M. septentrionalis* numbers were positively associated with increasing amount of forest cover in PEI (Henderson *et al.* 2008) and NF (Park and Broders 2012) and *Perimyotis subflavus* in NS were negatively associated with amount of non-forested land (e.g., agricultural, clearcut sites) (Farrow and Broders 2011).

Habitat Trends

Hibernacula are permanent structures that may be used for many years because they have specific, unchanging micro-climates suitable for over-wintering bats. The quality of the habitat generally has declined wherever WNS has established; after two years' exposure to WNS, most hibernacula are fully infected and declines of over 90% have been typical (see **Fluctuations and Trends** section). Spores of *Pd* likely persist (see *Transmission and Risk of Infection* section) and infected sites act as population sinks and are functionally no longer available. Closure of abandoned mines may represent lost overwinter habitat, but is unquantified.

Summer habitat for the three species is characterized as foraging and roost locations, with the emphasis on roosts, and particularly maternity colonies. *Myotis lucifugus* maternity colonies often are in buildings (Henderson *et al.* 2008), although this may be biased by easier detection because sites are reported by the public. For *M. septentrionalis* and *Perimyotis subflavus*, the extent of habitat loss for summer roosts cannot be quantified because of the variable intensity of forest harvest and practices across the species' large range. Also, the structures most associated with maternity colonies are difficult to identify, and have not been inventoried. The age of forest can be used as a coarse indicator of trends in the amount of roosting habitat. Intensively managed stands (*i.e.*, even-aged plantations with short rotation periods) over large areas could be a decrease in habitat because they typically create a forest with fewer large-diameter trees and snags that could house roost and maternity colonies (Hayes and Loeb 2007). Selective harvesting (as compared to clearcuts) can maintain large-diameter snags and is the common harvesting method in most sub-boreal forest types, but clearcut harvesting is the dominant harvest type in most of the boreal forest in Canada. In 2010, for example, 88% of 690,000 ha were cut with one or two-stage (clearcut) harvest, and most of this was in the boreal forest (National Forestry Database 2012). Large openings, such as clearcuts, are avoided for foraging (see **Habitat Requirements** section) but how much of an area has to be open before bats respond in abundance, or fitness, is unknown.

Historical conversion of forest to agricultural or urban conditions is prevalent in much of the Canadian range of *Perimyotis subflavus*, and the southern regions of the Canadian range of *Myotis lucifugus* and *M. septentrionalis*, particularly in Ontario and Quebec, and parts of AB and BC. Parts of some regions, such as in eastern Ontario, have reverted from agriculture to forest cover (Lancaster *et al*. 2008), which likely increased the amount of bat summer habitat. In summary, the overall amount of habitat for the three species is unknown.

BIOLOGY

General

The following information on general biology and reproduction of the three species is derived from species accounts by Fenton and Barclay (1980), Fujita and Kunz (1984), and Caceres and Barclay (2000), unless otherwise referenced. All three species consume a wide range of insects and spiders. Spiders are gleaned from webs, while insects are captured in flight. Prey items range from 4-10 mm and are dominated by Diptera (mainly chironomids [particularly for *Myotis lucifugus*]), Coleoptera (carabids), Homoptera (cicadillids), Hymenoptera (formicids), Trichoptera, and Lepidoptera.

Life Cycle and Reproduction

All three species are promiscuous, with mating occurring during late summer/autumn swarming periods, and during winter. Females store sperm and ovulate in spring with a single pup (potentially two pups for *Perimyotis subflavus*) born after a 44-60 day gestation period, usually in late June or early July. Females form maternity colonies to birth and raise the pups. Pups are weaned at approximately 26 days (Burnett and Kunz 1982). Sexual maturity generally occurs after the first year and breeding occurs for life.

The demographic population structure is poorly known for all three species, particularly in Canada where parameters such as reproduction and survivorship likely vary from those used in studies conducted in the US. Reproductive rates for *Myotis lucifugus* vary and generally decline with increasing latitude (Barclay *et al*. 2004). Higher rates are reported in eastern areas (e.g., >96 % in eastern US, Cagle and Cockram 1943; Humphrey and Cope 1976), and lower rates in northwestern areas (e.g., 42-57% in BC, Firman *et al*. 1995, Holroyd *et al*. 1993, C. Lausen, unpub. data). The lowest and most variable rates seem to be from the northern edge of the range; maternity colonies in Yukon are reported to vary between sites and years, with reproductive rates of 33-74% (Talerico 2008).

Survivorship is an important component of generation length and population trend criteria used in a COSEWIC assessment. Unfortunately, there is uncertainty with the application of most specific survival data because of problems in design and analyses. Average survival rate of *Myotis lucifugus* from band recoveries in Indiana was 1.55 years for males and 1.2-2.2 for females, but these rates were considered underestimates (Humphrey and Cope 1976). Mean annual survival of *M. lucifugus* in Ontario was 0.82 for males (monitored for 16 yrs) and 0.71 for females (monitored for 10 yrs) (Keen and Hitchcock 1980) but the conclusions are limited because the number of juveniles in the sample is unknown. In Indiana, average life expectancy after year one for *M. lucifugus* was 3.8 years for males, and 6.5 years for females (Humphrey and Cope 1976).

Movement by bats during winter is such a significant problem for survivorship estimates that it is now recommended that closed-population methods should be avoided, and missing animals cannot be assumed to be dead (O'Shea *et al*. 2004; O'Donnell 2009). Instead, robust design survivorship techniques that partially account for temporary emigration should be used. To date, however, there is only a single study (Frick *et al*. 2010b), and only on *Myotis lucifugus*, that has a long-enough time period to begin to minimize variability in recapture probabilities and survival estimates (O'Donnell 2009). In this study, Frick *et al*. (2010b) reported on *M. lucifugus* that were monitored for 16 years in a summer maternity colony in New Hampshire. Survivorship of adult females was highly variable and ranged from 0.63-0.90, depending on amount of cumulative precipitation over the summer. Juvenile female survivorship was lower, ranging from 0.23-0.46. Survivorship was higher for juveniles born later in a summer versus early summer. Survivorship is lowest in the first year of hibernation because juveniles often lack sufficient fat reserves needed for hibernation (Fenton and Barclay 1980).

Although rigorous, the Frick *et al*. (2010b) study still does not fully address the survivorship issue. The survivorship of juveniles likely is still an underestimate because the proportion of one-year-old females returning was variable (23-53% probability) and a robust design accounts for temporary emigration, but not permanent emigration. Recapture rates from 2,891 (1295 juvenile:1596 adult) female bats were low (0.10-0.35). Also, survivorship for males is unknown; males often do not return to maternity colonies after weaning.

A similar problem exists for data on *Perimyotis subflavus*. Using returns on banded *P*. *subflavus*, Davis (1966) concluded survivorship was low in first and second winters (0.41-0.51 adult female; 0.46-0.68 adult male), high in the third year (0.74 adult female; 0.98 adult male), then declined again. Baker (1978) refuted those results, noting that much of the movement out of caves occurs in year one and two, whereas residency is high in year four, and movement again increases, a behaviour that would explain Davis's estimates. Baker suggested that survivorship estimates are poor without accounting for intra-cave movement. The Davis results have also been questioned by O'Shea *et al.* (2004) because of faulty correction factors used on recapture data.

Generation Time

Two methods (median age of breeding/longevity, and mean age of cohort breeding; IUCN 2011) are used to estimate a range of generation time because neither method is satisfactory by itself. The mean age of cohort breeding is the preferred method (IUCN 2011) but existing data on estimating annual survivorship is limited and biased (see **Life Cycle and Reproduction** section). For the median age method, *Myotis lucifugus* and *M. septentrionalis* start breeding after one year old, continue breeding annually, and have been recorded to live over 30 (Fenton and Barclay 1980), and 19 years (Hall *et al.* 1957), respectively. *M. septentrionalis* likely live to be the same maximum age (≈30 yrs) as the similar *M. lucifugus* and the two species are considered together here. Using the median age of longevity method, generation length is 14 years (median of 15, minus one year to account for the sub-adult period).

However, the median age method may overestimate generation length if few bats reach maximum lifespan, and this seems to be the case. For example, a long-term study in Manitoba indicated that the proportion of *Myotis lucifugus* >3 years is low and few bats are >20 years old (C. Willis, unpub. data) and in Yukon, 26% of bats banded as adults were recaptured after nine years, and 9% were recaptured after 10-14 years (B. Slough and T. Jung, unpub. data). Therefore, it was deemed important to also determine generation length from the mean age that a cohort breeds. Data from several studies were used; the Frick *et al*. (2010b) study is the most rigorous but only has data on females at summer maternity colonies. A Canadian study (Keen and Hitchcock 1980) is biased but has data from both sexes in hibernacula. Using the Generation Length calculator (IUCN 2011) with both data sets leads to an estimate ranging from 4-10 years (Frick *et al*. 2010b) and 3-17 years (Avg. 4 yrs) (Keen and Hitchcock 1980) for females. For males, applying the average survival rate (Keen and Hitchcock 1980) over 30 years suggests a generation length of six years (range 4-10 yrs). A combination of results from both studies would suggest that the generation time for both species is approximately five years.

In summary, because the median age of breeding/longevity potentially overestimates generation time, while mean age of cohort potentially underestimates it, the most plausible estimate for generation time for *M. lucifugus* and *M. septentrionalis* is a range of 5-10 years, based on both methods.

Perimyotis subflavus:

Mean breeding age is unknown but wild *P. subflavus* start breeding after their first year, continue breeding annually, and have been recorded to live over 15 years (Walley and Jarvis 1971). This suggests the median age of breeding is seven years for *P. subflavus* (median age of maximum longevity is eight minus one year to account for the sub-adult period). Although the survival data analysis for the species (Davis 1966) is biased (see **Life Cycle and Reproduction** section), the data are the best available; using these data in the Generation Length calculator (IUCN 2011) leads to an estimate of five years (using both sexes combined and with either one or two offspring annually after year one, for 14 years). This suggests a range of 5-7 years as a plausble estimate for generation time for *P. subflavus*.

Physiology

The physiology of non-migratory, temperate bats is well-studied, mainly because of interest in the ability of such species to process fat reserves into energy and rapidly enter and exit torpor, while balancing energy intake and expenditure as a small-bodied, flying mammal possessing a large surface area (Studier and Howell 1969; Fenton and Barclay 1980; Willis 2006). Only the physiological aspects related to a status assessment are presented in this report.

Bats survive the winter using stored fat reserves accumulated during summer/autumn (Jonasson and Willis 2011). They then minimize use of these reserves by decreasing body temperature to within a few degrees of the ambient temperature in the hibernaculum, with a corresponding 96-98% reduction in metabolic rate (Henshaw and Folk 1966). The decreased metabolism is facilitated by overwintering in a cold environment. The optimal ambient temperature for maintaining the lowest metabolic rate is 2°C for *Myotis lucifugus* (and presumably similar for *M. septentrionalis* and *Perimyotis subflavus*) (Hock 1951). However, functioning at such a low temperature creates an extra energetic cost to arouse and access water, a higher energetic cost to maintain core temperature when temperature fluctuates, and increases predation risk (Boyles and McKechnie 2010). As a result, it is more efficient to hibernate at a temperature a few degrees above the minimal level; most small bat species typically hibernate where the temperature is 2-10°C (Anderson and Robert 1971).

At 5°C, *Myotis lucifugus* arouse from torpor every 13 days, on average (Brack and Twente 1985; Twente *et al.* 1985), approximately 15 times a winter (Thomas *et al.* 1990). Bats will arouse from torpor to access water, to groom, and to mate (Avery 1985; Whitaker and Rissler 1993; Thomas 1995). Each arousal event requires approximately five minutes to one hour (C. Willis, pers. comm.), and three hours to re-enter hibernation, consuming up to 109 mg fat per event and 29% of their total body mass over a winter (Thomas *et al.* 1990; Jonasson and Willis 2011, 2012). A bat in flight consumes greater amounts of fat. This energy budget is relevant to bat conservation because bats at the northern edge of their range in Canada spend longer periods in hibernation (Fenton and Barclay 1980; Fujita and Kunz 1984) and likely are more vulnerable to disturbance than those in warmer climates.

Water balance also is important for hibernating bats (Thomas and Geiser 1997). Humidity levels need to exceed 99% to compensate for the evaporative water loss of a hibernating bat (Thomas and Cloutier 1992). Moisture loss is a particular problem because the non-furred wing and tail membranes represent a high proportion of body surface area (Thomas and Cloutier 1992). The humidity levels of hibernacula always exceed 65% relative humidity, and usually exceed 90% (Fenton 1970a; Raesly and Gates 1987; Kurta and Teramino 1994).

Adaptability

Insectivorous bat species survive the lack of insects in winter by migrating south, or overwintering in hibernacula. The northern limit of an overwintering species appears related to winter temperature (Humphries *et al.* 2006; Boyles and Brack 2009), ability to cluster as a group and thereby maintain body temperature (Boyles *et al.* 2008), and physiological thermal neutral zones, as determined by local adaptations (Dunbar and Brigham 2010). *Myotis* bats typically hibernate with their own species but in clusters of two to thousands of bats, either touching, or within a few centimetres of each other (Tuttle 2003). *Perimyotis subflavus* typically roost singly (Barbour and Davis 1969). Hibernation likely lasts from late September/October to late April/early June in much of the Canadian range of the three species (Fenton and Barclay 1980; Fujita and Kunz 1984; Caceres and Barclay 2000). Emergence from hibernacula may be earlier along the Pacific coast than other regions (T. Jung, pers. comm.).

Interspecific Interactions

In eastern Canada, the three species often overwinter in the same hibernacula, but not in mixed-species clusters. In summer, foraging areas overlap, particularly for *Myotis lucifugus* and *Perimyotis subflavus*, both of which commonly forage over water. Numerous other species of bats (e.g., *Lasiurus cinereus*, *L. borealis, Eptesicus fuscus*) forage in the same areas with the three species in much of the Canadian range (van Zyll de Jong 1985) but there is limited evidence of competition or interaction between any species during foraging. Davis and Mumford (1962) suggested, however, that *M. lucifugus* and *P. subflavus* may avoid each other while foraging because *P. subflavus* were generally absent where *M. lucifugus* foraged.

Predators of the three bat species are varied but not considered significant; no predator specializes on bats in Canada. Incidental observations of predation have been recorded for owls, rodents, domestic cats, snakes, and frogs (Fenton and Barclay 1980; Fujita and Kunz 1984; Caceres and Barclay 2000).

Several species of endo-, and ecto-parasites are common to all three species of bats, including various cestodes and trematodes, batbugs (*Cimex* spp.), fleas (*Myodopsylla* spp.), and mites (*Euschoengastia*, *Macronyssus*, *Spinturnax*) (Fenton and Barclay 1980; Fujita and Kunz 1984; Sasse and Pekins 2000; Poissant and Broders 2008; Czenze and Broders 2011). Differences in parasite abundance exist between males and females (Czenze and Broders 2011) and between maternity colonies (T. Jung, pers. comm.), but it is unknown if susceptibility to WNS is associated with parasite abundance or diversity.

North American rabies is caused by a virus (family Rhabdoviridae, Genus *Lyssavirus*) typically transmitted by saliva among mammals. The following summary is derived from the review by Messenger *et al.* (2003). The impact of rabies on bats is not clear because recorded die-offs may not be entirely due to rabies, and there is evidence of a degree of immunity in bats (*i.e.*, 2% of *Myotis lucifugus* showed antibodies to the virus, but no lesions in the brain). However, immunity is difficult to confirm because extended incubation periods of >1 year are known and 'immune' bats may not yet have been clinically affected. Prevalence is difficult to establish because of sampling bias but it appears a proportion of bats are rabid at any one time (*i.e*., <4% in a sample of apparently healthy *Eptesicus fuscus*, and <1% *in M. lucifugus* [Girard *et al*. 1965]). There is evidence of Red Fox (*Vulpes vulpes*) being infected by bat rabies strains in association with living in caves or dens, and presumably feeding on, or interacting with bats (Daoust *et al*. 1996; Messenger *et al.* 2003).

Dispersal and Migration

Dispersal

Little is known about dispersal behaviour of the three species. Most data are on seasonal movements between summer and winter range, rather than permanent dispersal from natal range. Newborns are difficult to mark and most studies rely on recaptures of banded juveniles, which are generally very low. Based on existing data, most females do not appear to disperse far; female *Perimyotis subflavus* (Veilleux and Veilleux 2004) and *Myotis lucifugus* (Frick *et al*. 2010b) often return to the maternity colony where they were born and weaned. Natal philopatry also occurs in female *M. septentrionalis* (Arnold 2007). Males typically do not return to natal sites and their dispersal movements are less understood.

Space Use

Peak foraging activity typically is in the first few hours after dusk, and often again before sunrise (Fenton 1970b; Kunz 1973; Broders *et al*. 2003). *Myotis lucifugus* in southeastern Ontario roosted at night only if ambient temperature declined below 5°C (Barclay 1982). All three bat species forage within small (*i.e.*, <2 km^2) areas. In Indiana, the summer roosting area of *P. subflavus* ranged from 0.1-2.3 ha, with a range of 21-926 m between roost trees (Veilleux and Veilleux 2004). In Michigan, 11 radio-tagged *M. septentrionalis* moved an average of 333 m ± 88 S.D. (range: 6-2,000 m) to new roost sites every two days over a 9-day tracking period (Foster and Kurta 1999). Average distance from capture to roost site for 18 radio-tagged *M. septentrionalis* in NF was 1,136 m (range: 71-2,375m) (Park and Broders 2012) and 1,100 m on PEI, with a minimum foraging area of 6.1 ha (Henderson and Broders 2008). In the Yukon, radio-tagged female *M. lucifugus* moved at least 6.3 km nightly between their roost and foraging grounds (Randall *et al*. in press). Average home range of nine female *M. septentrionalis* was 65 ha (Owen *et al*. 2003). Lactating *M. lucifugus* in Quebec reduced their home range area from an average 30.1 ha (± 15 S.D.) to 17.6 ha (± 9.1 S.D.) and foraging distance from 2.6 km (± 0.6 S.D.) to 1.7 km (± 0.6 S.D.) between pregnancy and lactation stages, likely to facilitate feeding of young at the roost (Henry *et al*. 2002).

Most of the known hibernating bats of a region are found in only a few hibernacula. For example, four hibernacula in Minnesota contain 99% of their known overwintering population (Nordquist 2000), eight hibernacula contain 75% of Virginia's bats (Dalton 1987) and many of the bats in several New England states are believed to hibernate 'in a few sites' along the Vermont and New York state border (Davis and Hitchcock 1965). In NB, one hibernaculum contained 86% of the known hibernating *Myotis* and the remaining nine sites had <300 each (Vanderwolf *et al*. 2012). In NS, Hayes Cave had 17,000 bats, compared to <3,500 in all others (H. Broders, pers. comm.). Similar situations exist for Manitoba (*i.e.*, 9,000 *M. lucifugus* in one cave; Dubois and Monson 2007; C. Willis, pers. comm.) and Alberta (Schowalter 1980; Lausen and Barclay 2006). However, so few hibernacula have been discovered across much of the range that it is difficult to determine average density per hibernaculum (C. Willis and H. Broders, pers. comm.).

Migration

All three bat species are considered short-distance regional migrants with a small proportion moving hundreds of kilometres between summer and wintering areas (Barbour and Davis 1969; Fenton and Barclay 1980; Fujita and Kunz 1984; Caceres and Barclay 2000). Distances of 35-554 km were recorded in Manitoba for banded *Myotis lucifugus* moving between winter hibernacula and summer maternity sites (Dubois and Monson 2007; Norquay *et al*. 2013) and *M. lucifugus* were recaptured as far as 250 km from summer maternity colonies in Ontario (Fenton 1970a).

Most bats seem to return to the same site annually; 94% of recaptures of 10,432 banded *Myotis lucifugus* from Manitoba over a 21-year period were only recaptured at a single hibernaculum or summer colony (Norquay *et al*. 2013). A small percentage (0.8%) were recaptured in a new summer or winter location from where they were initially captured. Although relocations were rare, the distances moved by bats from one hibernaculum to another (*n*=54) were considerable; 13 (25%) of these bats moved >500 km (range: 6-569 km) (Norquay *et al*. 2013). It appears movement between hibernacula occurs annually by a small percentage of bats (Griffin 1940, 1945; Fenton 2012). In Ontario, Fenton (1970a) recaptured four *M. lucifugus,* 45-125 km from a previous capture site, of which two animals moved to different caves in the same winter. Bats have been recorded swarming at one site but hibernating in another (Humphrey and Cope 1976, Norquay *et al*. 2013). A single banded *M. lucifugus* captured in northern Ontario was recaptured while swarming at Renfrew Mine in southwestern Ontario in September 1967, and again at the original northern site one month later, 800 km away (Fenton 1969).

Migration by *M. septentrionalis* is less known but they likely have similar movements to *M. lucifugus*. *M. septentrionalis* typically returned to specific caves in homing experiments, including one bat that returned from 52 km in three hours after being captive for three days (Griffin 1945). Another *M. septentrionalis* was recaptured 13 km from its release point, four years later (Davis 1966).

The longest distance moved by *Perimyotis subflavus*, based on recapture of banded individuals, was 53 km (Griffin 1940) but there is some indirect evidence individuals may move up at least several hundred kilometres further. Fraser *et al.* (2012) found a sample of 24 of 73 males moved southward from their northern range, based on changes in stable isotope signatures. The movement was directional (*i.e.,* north-south, as compared to typical migration that radiates out from hibernacula; Fenton and Barclay 1980) and, because *P. subflavus* hibernate singly, the southward movement may be related to their need to keep warm. The maximum distance was from central Ontario to southwestern Ontario (approx. 780 km).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Bats are surveyed by acoustic survey or capture with visits into hibernacula to count bats, external visits to the mouth of the hibernacula, and wider area surveys in forests, farmland and urban areas. WNS would not be detected using acoustic surveys and capture data may detect WNS if bats were swabbed and/or if there was evidence of wing damage (see *Cause and Impact on Bats* section). Determining the direct impact of WNS on a population is best assessed by entering the hibernacula but few hibernacula are actually entered because of safety reasons. There has been an increasing reliance on acoustic work for detecting relative abundance and population trends, but this work mainly began after the arrival of WNS and is of limited use in comparing pre- and post-WNS trends.

Hibernacula surveys involve counts by one or more observers conducted between October and April. Confidence limits generally do not exist on population estimates. The ability to estimate bat numbers varies because some hibernacula (*i.e.*, mines) have low-lying, relatively smooth surfaces where accurate counts may be possible, while others (*i.e*., limestone solution caves) have narrow passageways that are too high or narrow to count bats. In some jurisdictions (*i.e*., Ontario, NB, NS) *Myotis* species are combined into a single estimate because it is too difficult to identify some species beyond several metres.

Data that combine species into '*Myotis*' are not a significant problem for a COSEWIC assessment because some criteria are based on percent change, rather than actual population numbers. Virtually all bats in central-eastern hibernacula in Canada are either *Myotis lucifugus* or *M. septentrionalis* (see **Abundance** section) and both species respond equally to WNS (see **Fluctuations and Trends** section). Therefore, recorded percentage declines can be assumed to apply to each species.

Summer surveys are conducted with live-capture mist nets or harp traps set along trails, near waterways, nursery colonies (*i.e*., Slough and Jung 2008), or at hibernacula entrances. Acoustic surveys have been commonly used since the early 1990s and involve hand-held or automated recording of distinctive echolocation signals with specialized 'bat detectors'. *M. septentrionalis* make quieter echolocation calls, and likely are under-sampled (Fenton and Bell 1991). Determining abundance estimates is difficult because the same bat may be counted repeatedly; duplication can be avoided if bat detection occurs from a vehicle that is travelling faster than a flying bat (Roche *et al*. 2011). This method has been employed in the northeastern US since 2009 (C. Herzog, pers. comm.) and in parts of Ontario since 2010 (J. Bowman, pers. com.). Data collected using this technique do not exist before the impact of WNS, except for Quebec, which has conducted acoustic surveys on roads in several regions since 2000 (Jutras *et al.* 2011).

Most information on subpopulations is derived from local studies that capture and wing-band animals for later recapture. Projects with data exceeding 10 years are few but have been undertaken in Ontario (Hitchcock 1965; Fenton 1970a), Manitoba (C. Willis, pers. comm.), and Yukon (Slough and Jung 2008). Banding with pit-tags has begun in Manitoba and NS, but these are for shorter time series (H. Broders and C. Willis, pers. comm.).

Some jurisdictions have estimated the number of bats but mark-recapture methods typically were not used and the estimates are coarse. Winter data are constrained by the number of hibernacula visited, detectability of bats in different hibernacula, and unknown number of total hibernacula. Often, more bats appear to be present in summer than are recorded in winter. Due to the limited search effort, it is believed that the discrepancy is due to unidentified hibernacula, rather than most bats migrating out of Canada. There is seasonal movement in *Myotis* bats (see **Migration, Wind Turbines** sections) but movements would be considered regional, with some proportion of Ontario and Quebec bats hibernating in upper NY and Vermont, and though not reported, possibly bats in the Maritimes hibernating in upper New England.

Abundance

This report separates the population data into two periods; a pre-WNS period and a post-WNS period. The pre-WNS data are presented in the **Abundance** section. The post-WNS data are presented in the **Fluctuations and Trends** section.

The population sizes of the three bat species in Canada are unknown pre- or post-WNS. Relative abundance patterns across the range of each species are unknown, and the question remains as to whether they are as abundant in northern and western parts of their range as they appear to be in northeastern North America. Kunz and Reichard (2010) suggested that most of the pre-WNS population of *Myotis lucifugus* resided in the northeastern US. In Canada, 95% of the hibernating *Myotis* bats (combined *M. lucifugus* and M. *septentrionalis*) that have been counted occur in the range from NS to Manitoba, with relatively few bats having been recorded west of Manitoba (see below).

However, the number of *Myotis* spp. in the north and west that have been counted relative to the east may not be a true reflection of regional relative abundances. Hence, the proportion of the population in western Canada is unknown.

At present, WNS has affected approximately 30% of the Canadian range of *M. lucifugus*, 40% of *M. septentrionalis*, and close to 100% of *P. subflavus*. Estimates of overall decline already experienced by the Canadian populations of the two *Myotis* species are not possible without knowledge of either the proportion of the Canadian populations that has already been affected by WNS, or the proportion residing in the area of Canada where WNS has not yet appeared.

Myotis lucifugus:

The population size is unknown but available data suggest that *M. lucifugus* is the most common bat in much of Canada; they are frequently the most recorded in surveys and buildings during summer and are observed over many ponds, rivers, and lakes across their range (Fenton and Barclay 1980). The pre-WNS estimate for NS was 300,000 in summer (based on numbers at lakes and extrapolated to total number of lakes) and 30,000 at known hibernacula in winter (Scott and Hebda 2004). In Quebec, *M. lucifugus* are considered common (echolocation surveys in Quebec do not separate *Myotis* calls into species and more exact numbers are unavailable; Jutras *et al*. 2011). Data on abundance in the prairie region of Saskatchewan are unavailable but *M. lucifugus* is considered common in similar, adjacent habitat of North Dakota (Jones *et al*. 1983). In Alberta, the species is considered common in the Prairie region near Calgary (Coleman and Barclay 2011). The typical abundance in 196 maternity colonies was 50-300 bats (range 15 - 1100) (Schowalter *et al*. 1979). The species is relatively common in summer in parts of BC (Nagorsen and Brigham 1993) but rarer in other parts; *M. lucifugus* comprised 9% (39 individuals) of a sample of 11 species in the Okanagan valley region (Fenton *et al*. 1980). Over three years of survey in southern BC, *M. lucifugus* (based on genetics, morphology, acoustics) comprised 20% of the 805 captures of 14 species (C. Lausen, D. Nagorsen, D. Burles, unpub. data). Mis-identification may be an issue in BC; differentiating *M. lucifugus* from *M. yumanensis* is difficult (Luszcz *et al*. 2003; Weller *et al*. 2007) and identification on morphology alone had an error rate up to 34% (C. Lausen, unpub. data). Historical data on *M. lucifugus* needs genetic confirmation because *M. yumanensis* appears to be common in the datasets, which raises the possibility of misidentification errors (C. Lausen, pers. comm.). Abundance levels in the northern end of their range are harder to estimate but *M. lucifugus* is considered relatively common. For example, based on mark-recapture population estimates, some maternity colonies in the Yukon have >800 bats (Jung 2013).

Overwintering data for *Myotis lucifugus* are patchy, with extensive data existing for some sites in southern Ontario and Quebec, but limited elsewhere, particularly in NL, NT, and PEI where mainly single sites have been surveyed (Brown *et al.* 2007, S. Moores, pers. comm., Lausen 2011). The PEI site contained 648 (83%) *M. lucifugus* (Brown *et al.* 2007). In NS and NB, *Myotis* sp. are combined during surveys but *M. lucifugus* appear much more common; in an NB sample of bats killed by WNS, 91.6% were *M. lucifugus*, which would extrapolate to 6,466 *M. lucifugus* in the 10 hibernacula at the onset of WNS (D. McAlpine, pers. comm.). In Quebec, the total abundance estimate from five caves was 13,108 *M. lucifugus* in 2007/08 (Mainguy *et al*. 2011). In Ontario, two mines each contained approximately 10,000 overwintering bats annually (Fenton 1970a). In Manitoba and northwestern Ontario, 11 hibernacula contained >10,000 *M. lucifugus*, most of which were in one cave in Manitoba (Nagorsen 1980; Dubois and Monson 2007; C. Willis, pers. comm.). The four known hibernacula in Alberta contain approximately 1,980 *M. lucifugus* (D. Hobson, pers. comm.) and only a few bats have been recorded in mines in central BC (Nagorsen and Brigham 1993). A total of 3,000 *M. lucifugus* were recorded overwintering in a single site in southern NT (Lausen 2011). The Canadian population size of *M. lucifugus* is unknown but foraging individuals appear to be present on most waterbodies within its large range; the population likely exceeded one million bats before the arrival of WNS.

Myotis septentrionalis:

The population size of *Myotis septentrionalis* is unknown but they are less common than *M. lucifugus* and have a more restricted distribution on the landscape, likely due to their reliance on forested areas. Captures at swarming sites during autumn in NS over the last 10 years yielded 1,678 *M. septentrionalis* versus 4,249 *M. lucifugus* (H. Broders, pers. comm.). Schowalter (1980) recorded 10 *M. septentrionalis*, compared to 899 *M. lucifugus*, swarming at two hibernacula in Alberta. In contrast, Grindall *et al*. (2011) captured 260 *M. septentrionalis*, compared to 193 *M. lucifugus*, in mist nets in the oil sands region of northeastern Alberta. The species appears to be relatively common in southern NT (J. Wilson, pers. comm.) and uncommon at the edge of their western and northern range (T. Jung, unpub. data); 15 (15.1% of a total 98 bats of seven species) were captured from 332 net-nights over two summers in the Columbia River valley of BC (Caceres 1998). On Newfoundland, similar numbers of *M. lucifugus* (n=22) and *M. septentrionalis* (n=29) were captured in 280 trap nights during summer 2008 (Park and Broders 2012). Similar evenness was found in PEI (Henderson *et al.* 2009) and less so in NS (127 *M. lucifugus* versus 37 *M. septentrionalis*), but the main trap site was at a bridge that may have favoured *M. lucifugus* (Poissant *et al.* 2010).

Relatively few (*i.e*., <100) *Myotis septentrionalis* are recorded in individual hibernacula (Barbour and Davis 1969; Caire *et al.* 1979; Amelon and Burhans 2006). The disparity between summer and winter abundance exists across the species' range, likely because *M. septentrionalis* may be harder to detect than *M. lucifugus* in hibernacula. Although *M. septentrionalis* are known to roost in clusters, they often roost by themselves, and use small openings to hide in (Whitaker and Rissler 1993). Abundance data for *M. septentrionalis* in winter do not exist for NL. In PEI, *M. septentrionalis* comprised 132 bats (17%) in the only known hibernaculum (Brown *et al.* 2007). In NS, *Myotis* species are not separated to species during hibernation counts but 1,678 *M. septentrionalis* were captured at the entrances to 17 hibernacula (H. Broders, pers. comm.). In NB, the two *Myotis* species are combined as *Myotis* sp., but *M. septentrionalis* comprised 8.4% of a collection of carcasses killed by WNS (D. McAlpine, pers. comm. 2012). In Quebec, Lafleche Cave had 17 *M. septentrionalis* and five *M. lucifugus* (Hitchcock 1940), and 58 *M. septentrionalis* were banded between 1939 and 1958, compared with 124 *M. lucifugus* (Hitchcock 1965). A total of 2,592 *M. septentrionalis* (19% of total *Myotis*) were recorded in five caves in 2008/09 (Mainguy *et al*. 2011). In Ontario, Hitchcock (1965) was confident he could capture most bats in five caves of the Ottawa-Belleville region, and identified 17 (18%), 58 (21%), six (0.5%), 183 (14%) and 96 (3.3%) as *M. septentrionalis*. A total of 117 *M. septentrionalis* (2% of total *Myotis*) and 5,712 *M. lucifugus* were recorded at Renfrew Mine (Fenton 1969). The pre-WNS Canadian population likely was >1 million animals.

Perimyotis subflavus:

The population size is unknown but the species is relatively rare in the Maritimes and Quebec, and rare or uncommon in parts of Ontario. It also is rare in adjacent US states of Vermont (Darling and Smith 2011) and Maine (Zimmerman and Glanz 2000). In NB, very low numbers (*i.e.*, 49 echolocation calls out of 160,000; <0.2%) of *P. subflavus* were recorded during summer (Broders *et al.* 2001). In NS, 12% of >30,000 echolocation calls, and 6% of captured bats during summer, were *P. subflavus* (Broders *et al.* 2003). Based on work from three graduate projects, H. Broders (pers. comm.) estimates 1,000-2,000 adult female *P. subflavus* existed in NS, pre-WNS. In Quebec, *P. subflavus* accounted for 30 (0.2%) of 10,268 total bat echolocation calls recorded between 2000 and 2009 on several (*i.e*., 3-15), 20-km-long summertime acoustic survey routes (Jutras *et al.* 2011). On Montréal Island, *P. subflavus* was the least recorded (4.3%) in echolocation passes among four bat species at 24 survey sites (Fabianek *et al*. 2011). The abundance of *P. subflavus* in Ontario appears patchy; records exist for central Ontario (*i.e*., Algonquin Park), and they are considered relatively common in the Kingston area of southeastern Ontario (MacDonald *et al*. 1994; B. Fenton, pers. comm.). However, *P. subflavus* was found only twice before 1940 (Hitchcock 1940) and was not recorded in summer at 198 survey sites in southwestern Ontario and the Bruce Peninsula during 133 hours of echolocation monitoring (Furlonger *et al*. 1987).

In most of the Canadian range, the numbers of *Perimyotis subflavus* recorded in hibernacula are similar to those recorded in summer, suggesting that the winter data are an adequate reflection of the Canadian population, and declines measured in hibernacula are valid. Of approximately 7,000 bats recorded in six NB hibernacula in 2010/11, only 20 (<0.2%) were *P. subflavus* (Vanderwolf *et al*. 2012). A similarly small number (47) were recorded at entrances to NS hibernaculum (H. Broders, pers. comm.). In Quebec, four (1.4%) of 281 total bats banded in Laflèche cave (Saint-Pierre de Wakefield) were *P. subflavus* (Hitchcock 1965). *P. subflavus* were recorded in two of five caves in 2007/08 and 2008/09 and accounted for 17 (0.1%) and 19 (0.1%) of all bats, respectively (Mainguy *et al*. 2011). In Ontario, a small proportion (*i.e*., 0.2, 1, 4.5%) of all bat species in caves of various sizes were *P. subflavus* (Hitchcock 1949, 1965).

Fluctuations and Trends

Prior to WNS (see **Threats** section), regional populations were believed to be relatively stable (Frick *et al*. 2010a; b), but populations at a local scale varied because individual bat colonies are susceptible to localized and rare events. For example, flash flooding in a Kentucky hibernaculum caused >5,000 deaths (DeBlase *et al.* 1965). An estimated 1,000 bats (*Myotis* sp. and Hoary Bats) died at a lake near Edmonton, AB due to exposure to a toxic alkaloid produced by blue-green algae (Pybus *et al.* 1986). Although these events cause significant mortality, they typically have been limited to single hibernacula or maternity colonies, and the larger population in the region is not substantially affected.

Population trend information is limited, and most information exists only for the area affected by WNS. Of 42 US subpopulations of *Myotis lucifugus* monitored over 10-30 years until the onset of WNS, 64% did not show a population trend, 31% increased, and 5% declined (Ellison *et al*. 2003). In Vermont, data on 23 hibernacula that have been monitored for variable periods (e.g., 10-60 years) indicate that the *M. lucifugus* population was generally stable or increasing, pre-WNS. Subpopulations at some hibernacula had intra-annual variation of +/- <20%, and several times declined by approximately 50% for periods of 2-3 years over a 60-year period (Trombulak *et al*. 2001). For *M. septentrionalis*, 25% of 12 pre-WNS subpopulations in the US were increasing, and 75% showed no trend (Ellison *et al*. 2003). The same trend of stable or increasing was recorded in the US for *Perimyotis subflavus* in 44 subpopulations.

Frick *et al*. (2010a) concluded that before WNS, 19 of 22 (86%) of hibernacula in the northeastern US had stable or increasing populations during the last 30 years. Data on regional subpopulation trends in Canada are unavailable; several studies occurred in southern Ontario (*i.e.,* Hitchcock 1965; Fenton 1970a; Keen and Hitchcock 1980) but these data are >30 years old.

Population declines of some cave-dwelling bat species in the eastern US have been documented since the 1950s (Mohr 1952; Pierson 1998) and several species, most notably the Indiana Bat (*Myotis sodalis*), are listed as endangered in the US.

An unprecedented decline began in 2006 with the arrival of WNS (see **Threats** section); an estimated one million bats (multiple species) died in the northeastern US within three years of the arrival of WNS (Kunz and Tuttle 2009), and 5.7 to 6.7 million bats have been estimated to have died within six years (U.S. Fish and Wildlife Service news release; January 17, 2012). The following trend information is presented for the northeastern US because WNS has occurred there for longer and the impacts have been well surveyed; impacts there foreshadowed events that have since occurred in the Maritimes, and are likely to occur in other parts of Canada. The total decline in *Myotis* bats known to be present in NS, NB, Ontario, and Quebec hibernacula at time of WNS arrival, to most recent data for the site, is 94% (86,952 to 5,225; see below). Recent events in Canada are presented after the US data. See Appendix 1 for a discussion on data issues.

<u>*Myotis lucifugus* - US Data</u>

A minimum of 115 hibernacula were infected with WNS four years after WNS was initially detected in North America; annual decreases in bats within hibernacula averaged 73% (range 30-99%) (Frick *et al*. 2010a). Most of these bats were *Myotis lucifugus*. Average decline in 54 hibernacula in six northeastern US states after two years' exposure to WNS was 91% for *M. lucifugus* (Table 1; Turner *et al.* 2011). Twelve of 54 sites declined to zero bats. As of 2011, WNS had been recorded in 190 hibernacula in 16 states and four provinces. A survey of state biologists in spring 2012 led to the conclusion that virtually all known significant hibernacula in the northeastern US were infected with WNS (Herzog and Reynolds 2012).

Table 1. Abundance of *Myotis lucifugus* at winter hibernacula in the northeastern United States that had a minimum of two years' exposure to White-nose Syndrome, as of 2011. Adapted from Turner *et al*. 2011, except for data from Maryland (D. Feller, pers. comm.).

State (# sites)	Population Pre-WNS	Population > 2 yr Post-WNS	Pre vs Post Difference (%)	# Sites Extirpated
New York (38)	326867	28890	-91	10
Pennsylvania (6)	14229	198	-99	1
Vermont (3)	644	26	-96	1
Virginia (2)	4844	1032	-79	0
West Virginia (3)	394	26	-93	0
Maryland (4)	832	59	-93	1
Total (56)	347810	30231	-91	13 (23%)

Note: For Vermont, species identification facilitated by all sites having low ceilings (S. Darling pers. comm.).

Myotis lucifugus is predicted to be functionally extirpated (*i.e.*, 1% of pre-WNS population) in the northeastern US by 2026 (Frick *et al.* 2010a). The population analysis used population growth rates from 22 hibernacula in the northeastern US over 30 years, calibrated with specific growth rates from a detailed study population (Frick *et al*. 2010b), and compared declines in infected versus uninfected sites. Simulations on a stochastic population model started with 6.5 million bats and predicted population levels at various rates of infection in hibernacula, while assuming a growth rate of 1.08. Using average declines recorded in the first three years of infection (of 85, 62 and 45% in years 1-3, respectively) and fixing future decline rates at 45%, the subpopulation had a 99% probability of extinction by 2026. If future declines are 10% per year, the probability of extinction is 90% within 65 years. Population declines rates would need to be <5% to significantly decrease the probability of extinction in 100 years.

When available, summer data indicate declines similar to those reported during winter. Dramatic declines of >70% are consistent across the region, regardless of location and method of detection (Table 2). Dzal *et al*. (2011) recorded a 78% decline in summer activity of *Myotis lucifugus* within 100 km of the original WNS site, two years after exposure. A 72% decrease in activity (mainly *M. lucifugus*; Brooks 2009) was recorded in central Massachusetts after WNS (Brooks 2011). In northwestern NY, *M. lucifugus* activity declined significantly in a comparison before and after WNS, with a decrease from 14 to 2 mean echolocation passes/hour in late summer (Ford *et al*. 2011). Monitoring results from surveys of summer maternity colonies of *M. lucifugus* in Massachusetts indicated declines of >70% over the last three years (Gillman *et al.* 2011; unpub. data) and correspond to average decline for bats based on winter data (Frick *et al*. 2010a). In West Virginia, annual capture rates of *M. lucifugus* after one year of WNS declined by 80%, compared with a 12-year, pre-WNS period (Francl *et al*. 2012).

Table 2. Summary of change *Myotis lucifugus* abundance indices derived from various methods in the northeastern United States during the non-hibernation period, before or during early infection of White-nose Syndrome, compared with abundance indices after several years of exposure to White-nose Syndrome. Survey methods in references.

State	Pre/Early WNS Data (year)	Post-WNS Data (year)	Difference (%)	Source
New York				
Acoustic Survey (northwest)	Avg. 14 passes / hr	2	-86	Ford *et al*. 2011
Acoustic Survey (Albany area)			-78	Dzal *et al*. 2011
Vermont				
Spring Emergence Trapping	56.5 / hr (2008)	10.7 (2010)	-81	
Mist Netting (28 sites)			-99	
Maternity Colony				all data from Darling and Smith 2011
a) historical colonies	6 active sites	1 (2010)	-83	

State	Pre/Early WNS Data (year)	Post-WNS Data (year)	Difference (%)	Source
b) recent colonies	250 counted	63	-75	
Acoustic Survey				
a) Rutland wind farm	45 passes/detector night (2007)	7 (2010)	-84	
b) Fixed sites; all Myotis *sp.*			-88	
c) Camp Johnson; all Myotis *sp.*	56% of all calls (2007)	5 (2010)	-91	
Fall Swarm Trapping; 2 mines				
a) Elizabeth (effort was constant)	124 / trap hour (2006)	0.2 (2010)	-100	
b) Frostbite (effort was constant)	58 / trap hour (2005)	0 (2010)	-100	
Massachusetts				
Acoustic Survey	Avg. 6.0 +/-1.73 calls/hr (2004-06)	1.67 +/-0.84 (2010)	-72	Brooks 2011
Maternity Colony			>- 70 last 3 years	Gillman *et al*. 2011
Virginia				
Fall Swarm Trapping (5 sites)	Avg. 14 captures pre-WNS	2 (2011)	- 86	R. Reynolds pers. comm.
West Virginia				
Summer Mist Netting (44 sites; same sites and effort)	Avg. 16.9 captures (2005-08)	4.6 (2011)	-73	C. Johnson, pers. comm.
Mist Netting	0.836 capture rate per net night	0.168	-80	Francl *et al*. 2012

Myotis lucifugus - Canadian Data

Declines in regions where WNS has established in Canada have been similar to those in the US. In eastern Ontario, eight hibernacula were inspected internally from 2009-2011 and each became infected, with an average total decline of 74% after one year, and 92% for three sites >2 years. The total decline from time of infection to most recent data has been 93% (Table 3). The number of *Myotis lucifugus* is unknown but they are considered the most abundant species, based on incidental identification during these surveys, plus past work (e.g., Fenton (1969) captured 5,770 *M. lucifugus*, 91% of all bats at some of these hibernacula). Data from capture and acoustic surveys in Ontario are not yet available (J. Bowman, pers. comm.).

Table 3. Abundance of *Myotis* species in all Ontario hibernacula that have pre- and post-White-nose Syndrome (WNS) survey data. WNS was first detected in Ontario in winter 2009/10. Data courtesy of L. Hale (OMNR).

	Winter						
Hibernaculum in WNS Range	**2009/2010**	**2010/2011**	**2011/2012**	**2012/2013**	**% Change 1 year after**	**% Change 2 years after**	**% Change since 1st detection**
	Fall	**Fall**	**Fall**	**Fall**			
Craigmont	***30461***	24837	1457	1263	-18	-95	-96
Hunt (Renfrew)	***14378***	7005	2638	2097	-51	-82	-85
Crystal Lake	725	***539***	17	18	-97	-97	-97
Croft*		***3000+***	1537		-49		
Silver Crater		***251***	29	35	-88	-86	-86
MacDonald*		***21***	0		-100		
Watson		***96***	0	8	-100	-92	-92
Clyde Forks		***117***	7	1	-94	-99	-99
Total	n/a	min. 35866	5685	3422	-74	-92	
Regional Total	46049			3422			-93

Notes:

1) Population counts are conducted October-November. Survey data do not separate *Myotis lucifugus* or *M. septentrionalis.*

2) Values in bold italics indicate survey when WNS was first detected, as determined by visual or diagnostic methods.

3) * Croft and MacDonald sites were gated in 2012 after initial survey; only 50% of Croft was surveyed in 2010.

4) Regional total is best available data on total of maximum bat number recorded when WNS was detected that year in the region or at a site (46,049) and most recent number for the same sites (3,422). Data from Croft and MacDonald sites are incomplete and not included.

In Quebec, of four hibernacula with data before winter 2009/10 (WNS was first recorded in winter 2009/10), declines have been 98-100%; overall decline from all six sites with data before and soon after first incidence of WNS to last available survey is 98% (Table 4; Mainguy *et al*. 2011). In autumn 2011, Mine-aux-Pipistrelles, in southern Quebec near the US border and the closest site to the origin of WNS, decreased from >5,000 to eight bats (min. 99% decline), concurrent with hundreds of dead bats observed on the ground. Signs of WNS and “many dead bats” were recorded at another site (Emerald Mine) in February 2010. Most (99%) of the bats in the hibernacula were *M. lucifugus*.

Table 4. Abundance of *Myotis lucifugus* in all Quebec hibernacula with pre- and post-White-nose Syndrome surveys. All hibernacula are within WNS range. WNS was first detected in Quebec during winter 2009/10. (Source: Mainguy *et al*. 2011; J. Mainguy and A. Simard pers. comm.)

	Winter								
Hibernaculum	**2007-08**	**2008-09**	**2009-10**		**2010-11**	**2011-12**		**2012-13**	**% Change since WNS detection**
	Late	**Late**	**Early**	**Late**	**Late**	**Early**	**Late**	**Late**	
Halifax	856	823	780				3	0	-100
Mine-aux-Pipistrelles	5240	4795		***4393***		5		na	-99
Quebec Copper	3046	2760	3400				0	na	-100
Mine Emerald			***662***				12	25	-98
Trou de la Fée					263		***166***	57	-66
Caverne Laflèche					304		72	69	-77
Total	9142	8378	8525			186		151	-98*

Notes:

1) Abundance based on visual counts. 'Late' = March to April; 'Early' = November to February.

2) Value in bold italics = the survey when WNS was first detected at that site; Halifax and Copper sites likely had WNS in 2009/10. Most sites not surveyed in 2010/11 due to budget constraints.

3) % Change = difference between first detection at site, or year of detection in Quebec (2009/10), and most recent abundance estimate.

4) Only partial survey conducted at Quebec Copper in 2012 due to flooding, but areas surveyed should have contained bats, as in previous years.

5) Total only includes data from sites that were surveyed across years.

6) Additional sites have been surveyed (e.g., St. Robert Metal, Copperstream Frontenac) but are omitted because data do not extend past 2009/10 arrival date of WNS.

* Regional change is best available data on total of maximum bat number recorded when WNS was detected that year in the region or at a site (9,092 bats; 2009/10 – 2010/11), compared with most recent count (151 bats in 2012/13).

In NB, 10 sites were monitored for WNS in 2010-2013. The first record of WNS was in March 2011 when 83% of 6,084 bats in Berryton Cave died or disappeared in one month (McAlpine *et al.* 2011). The following winter, 350 bats were counted in December 2011, and zero bats in April 2013, two years later (Table 5). Bats typically remain in hibernacula until mid-May and so the reductions indicate decline, rather than bats leaving for the summer (D. McAlpine, pers. comm.). *Myotis* are combined as 'Myotis spp.' in the data but *M. lucifugus* are known to be present; 607 (66%) of 919 captures in August 2010 during swarming at Berryton and Whites Caves, and nine (20%) of 45 captures at Howes Cave in 2011, were *M. lucifugus* (H. Broders, pers. comm.). Also, a sample of 357 dead bats from the 2011 event in Berryton Cave contained 91% *M. lucifugus* (D. McAlpine, pers. comm.). During 2010-12, diagnostic testing and post-mortems confirmed WNS in 27 of 31 *M. lucifugus* collected from hibernacula and the landscape (S. McBurney, pers. comm.). By March 2013, WNS was recorded in all 10 known hibernacula, with declines of 33-100%; a total of 79 *Myotis* remain in the known NB hibernacula, as of April 2013. The average decline for NB from the first record of WNS to March 2013 was 99%.

Table 5. Abundance of *Myotis* species in all New Brunswick hibernacula that have pre- and post White-nose Syndrome survey data. WNS was first detected in New Brunswick in late 2010/11 (March). Data courtesy of D. McAlpine and K. Vanderwolf (NB Museum).

Hibernaculum	2008/09		2009/10		2010/11		2011/12		2012/13		% Change since 1st detection of WNS
	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	
Howes	182	117	171		200		221	***178***	128	15	-92
Harbell		10	23		32		33	29	***19***	1	-95
Kitts			24		15		***20***	6	4	0	-100
Markhamville			226			151	***272***	302	232	17 (+6 dead)	-94
Glebe Mine			159			155	192	***205***, 174	270	22 (+18 dead)	-89
Underground		336		237		243	***204***	53	19	13	-94
Berryton				934		***6087***	350	5	12	0	-100
White				211		192	***219***	46	23	9	-96
Dorchester							***140***	1	5	0 (+2 dead)	-100
Dallings		3	0	0	0		3	1 (+***2*** dead)	6	2	-33
Total			1985		***7075*** *		1654	794-825	718	79	-99^

Notes:

1) Abundance based on average counts from 2-3 surveyors; 'Late' = March to April, 'Early = November to February.

2) Values in bold italics = survey when WNS was first detected by visual methods.

3) % Change is difference between first detection of WNS and most recent count; repeat visits facilitated detection of decline that winter.

4) * Increase believed due to previously hidden bats moving to entrance, where most were found dead or infected with WNS.

5) Total only includes data from sites that are available across years. Percent change is total from 1st year of WNS being recorded (2011), to late 2013.

^ Regional change is best available data on total of maximum bat number recorded when WNS was detected that year in the region or at a site (7,473 bats; 2010/11 – 2011/12), compared with most recent count (79 bats in 2012/13).

Until 2012/13, most data on WNS in NS were from reports of winter-flying bats and submissions of >550 carcasses; 35 of 45 *Myotis lucifugus* tested from 2010-2012 were positive for WNS (S. McBurney, pers. comm.). The following data are from H. Broders (Saint Mary's University): WNS was first observed on bats in hibernacula in spring 2012 and all five sites were infected. Declines were evident in some caves (*i.e.*, 23, 25%) but one increased (27%), and overall there was a modest decline of 5% (Table 6). As predicted based on trends elsewhere, the second winter was catastrophic; in 2012/13, counts of *Myotis* (*M. lucifugus* and *M. septentrionalis* combined) decreased by 20,177 bats; declines of 89-99% were recorded in each cave, with an average decline for NS of 93%. The late winter count was conducted during the second week of April and it was expected that 2-6 weeks of hibernation remained. Therefore, whole winter mortality likely exceeded 93%. A high proportion was likely *M. lucifugus*; 71% of 5,974 bats captured at the entrances of the five hibernacula were *M. lucifugus*.

Table 6. Abundance of *Myotis* species in all Nova Scotia hibernacula that have pre- and post-White-nose Syndrome survey data. WNS was first detected in Nova Scotia in late 2011/12. Data courtesy of H. Broders (St. Mary's University).

	Winter										
Hibernaculum	**2008/09**		**2009/10**		**2010/11**		**2011/12**		**2012/13**		**% Change Since 1st detection of WNS**
	Early	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	
Cheverie	270			244		217	147	***200***	97	22	-89
Hayes						14923	17268	***16746***	16148	1511	-91
Minasville							769	***591***	899	31	-95
Rawdon	1335		1224		1213		1141	***860***	396	3	-99
Lake Charlotte*								***3351***	3347	4	-99
Total							19325	***18397***	20887	1571	-93^

Notes:

1) Abundance based on average of 2-3 independently derived, systematic counts by St. Mary's University staff.

2) Data on two additional sites not included because surveys have not been conducted after WNS detection.

3) Values in bold italics = survey when WNS was first detected.

4) * Site was surveyed three times (by unknown methods) with counts of 2,973 (1996/97), 2,079 (2000/01), and 2,761 (2003/04).

5) Total based on sites with data across years; Lake Charlotte data not included in 2011/12 total.

^ Regional change is best available data on total of maximum bat number recorded when WNS was detected that year in the region or at a site (22,729 bats; 2011/12), compared with most recent count (1,571 bats in 2012/13).

Fewer data are available for summer. In Ontario, numbers of bats using four of five maternity colony sites declined (range: 4-89%) and one site increased (12%) but overall percent difference in total maximum number per colony at time of WNS arrival to most recent data is -71% (Table 7). In Quebec, best available data from four maternity colonies indicate average decline of 96% (Table 8). Summer data from maternity colonies for population size or trends are not available for the Maritimes, except for recent declines noted in summer 2012 at four maternity colonies in NS where 'hundreds of bats are down to a few', including a decline from 45 to 11 female pit-tagged *Myotis lucifugus* at one site (H. Broders, pers. comm.). There are anecdotal reports of '*only a few bats'* being seen in parts of NB, but no quantitative data exist. In Quebec, acoustic data on roads suggest provincial abundance of *Myotis* sp. (*M. lucifugus, M. septentrionalis, M. leibii*, combined) had not significantly changed from 2000 to 2011. However, the lowest average abundance of *Myotis* was in 2011 and there were significant decreases in the Quebec, Lanaudière, Outaouais, and Abitibi regions of southwestern Quebec, where WNS has been recorded (N. Desrosiers, M. Delorme, A. Simard, and I. Gauthier, pers. comm. 2013).

Table 7. Abundance of *Myotis lucifugus* in all Ontario maternity colonies that have pre- and post-WNS survey data. White-nose Syndrome was first detected in Ontario in winter 2009/10. Data courtesy of L. Hale (OMNR).

Maternity Colony in WNS Range	2010		2011		% Change
	Late May	Mid-July	Late May	Mid-July	
Springtown Church		>500		53	-89
Foy Road		67		75	+12
Burnstown Church		400		58	-86
Cameron Farms	57		52		-9
Petawawa Church		81		78	-4
Total	1105		316		-71

Note:
Total % Change is difference between total maximum count per colony in 2010 (n=1105 bats) and total most recent count per colony (n=316 bats).

Table 8. Abundance of *Myotis lucifugus* in all Quebec maternity colonies that have pre- and post-WNS survey data. White-nose Syndrome was first detected in Quebec in winter 2009/10. Data courtesy of A. Simard.

Maternity Colony in WNS Range	1999	2000	2001	2004	2009	2010	2011	2012	2013	% Change
Domaine Joly, Lotbiniaire					1500		700	389	64	-94
Grosse-île, Bas-Saint-Laurent	201	162							4	-98
Fort Lennox, Montérégie						243			17	-93
Lac Fou, Portneuf			75	200		60	160	35	3	-99
Total % Change										-96

Note:

1) Values for Domaine Joly in 2009 and 2011 are estimates.

2) % Change is difference from highest to lowest count.

3) Total % Change is difference between total maximum count per colony in 2009 or later (n=2144) and most recent count per colony (n=88). Using only data since arrival of WNS, average decline based on three sites is -95%.

Myotis septentrionalis - US Data

The population trends of *Myotis septentrionalis* in the northeastern US mirror the results for *M. lucifugus*. Data from winter indicate that population declines in 32 hibernacula (infected for two years or more) in the northeastern US have been >98% for *M. septentrionalis* (Table 9; Turner *et al.* 2011). Bats were extirpated in 23 of 32 hibernacula (72%). Data from summer corroborate declines recorded in winter. All studies, conducted with a range of methods, indicate a decline of 30 to 100% (Table 10). A significant decline in bat activity was recorded by Ford *et al*. (2011) in northwestern New York, with declines from 0.7 to 0.4 mean echolocation passes/hour (43% decline). Preliminary results from 200 transects conducted during summer in 24 states indicates significant declines in summer abundance in WNS range (*i.e*., near extirpation of *M. septentrionalis* in New York with most transects no longer detecting this species; Britzke *et al.* 2011 unpub. data). Acoustic data are corroborated by capture data; the species was commonly captured pre-WNS but now is rarely caught in New York (C. Herzog, pers. comm.) with probability of capture declining from 0.3 to 0.015. In West Virginia, mist net surveys at the same 46 trap sites and with same trap effort documented significant decline from average 14.7 captures pre-WNS period (2005-2008) to 7.3 in 2011 (Johnson and Sanders 2012; C. Johnson, pers. comm.). A state-wide assessment of 5,469 *M. septentrionalis* captured in West Virginia found a 77% decline in capture rates between pre- (1998-2007), and post-WNS (2010) periods (Francl *et al*. 2012). In Vermont, trapping results at fall swarm events, and acoustic surveys at fixed sites, indicate dramatic declines (S. Darling, pers. comm.).

Table 9. Abundance of *Myotis septentrionalis* at winter hibernacula in the northeastern United States that had a minimum of two years' exposure to White-nose Syndrome, as of 2011. Adapted from Turner *et al.* 2011, except for data from Maryland (D. Feller, pers. comm.).

State (# sites)	Population Pre-WNS	Population >2 yr Post-WNS	Pre vs Post Difference (%)	# Sites Extirpated
New York (18)	619	17	-97	14
Pennsylvania (5)	940	2	-100	4
Vermont (3)	60	0	-100	3
Virginia (1)	7	9	29	0
West Virginia (3)	4	0	-100	1
Maryland (4)	12	0	-100	4
Total (32)	1642	28	-98	26 (79%)

Note: For Vermont, species identification facilitated by all sites having low ceilings (S. Darling pers. comm.).

Table 10. Summary of abundance indices for *Myotis septentrionalis* derived from various methods in the northeastern United States during the non-hibernation period, before or during early infection of White-nose Syndrome, compared to abundance indices after several years of exposure to White-nose Syndrome.

State	Pre/Early WNS Data (year)	Post-WNS Data (year)	Difference (%)	Source
New York				
Acoustic Survey (northwest)	Avg. 0.7 passes / hr	0.4	-43	Ford *et al*. 2011
Vermont				
Mist Netting (28 sites)			-93.2 captures	
Acoustic Survey				
a) Rutland wind farm	115 passes/detector night (2007)	80 (2010)	-30	all data from Darling and Smith 2011
b) Fixed sites; all Myotis *sp.*			-88	
c) Camp Johnson; all Myotis *sp.*	56% of all calls (2007)	5 (2010)	-91	
Fall Swarm Trapping; 3 mines				
a) Elizabeth (effort was constant)	35 captures / trap hr (2006)	0 (2010)	-100	
b) Frostbite (effort was constant)	36 / trap hr (2005)	0 (2010)	-100	
c) Yager (effort was constant)	24 / trap hr (2005)	0 (2010)	- 100	
Massachusetts				
Acoustic Survey	Avg. 6.0 +/-1.73 calls/hr	1.67 +/-0.84	-72	Brooks 2011
Maternity Colony			>- 70 last 3 years	Gillman *et al*. 2011
Virginia				
Fall Swarm Trapping (5 sites)	Avg. 21 captures pre-WNS	Avg. 2 (2011)	-90	R. Reynolds pers. comm.
West Virginia				
Summer Mist Netting (46 sites; same sites and effort)	Avg. 14.7 captures (2005-08)	Avg. 7.3 (2011)	-50	C. Johnson, pers. comm. Francl *et al*. 2012
Mist Netting	1.437 capture rate per net night	0.33	-77	

<u>*Myotis septentrionalis* - Canadian Data</u>

The average total decline of *Myotis* from Ontario hibernacula being monitored was 93% since detection of WNS (Table 3). *Myotis* are not separated to species in Ontario data but each of the eight hibernacula being monitored contained *M. septentrionalis* (L. Hale, pers. comm.). Based on results elsewhere, it is assumed that *M. septentrionalis* declined at similar rates as *M. lucifugus*. *M. septentrionalis* comprised 3.2% of 6,361 bats captured at 10 hibernacula in the same region from 1966-1968 (Fenton 1969) and their continued presence is likely. In Quebec, at the four sites with data after the arrival of WNS, *M. septentrionalis* abundance declined from 1,609 to 2 bats, a 99.8% decline (Table 11).

Table 11. Abundance of *Myotis septentrionalis* in all Quebec hibernacula with pre- and post-White-nose Syndrome surveys. All hibernacula are within WNS range. WNS was first detected in Quebec during winter 2010. (Source: Mainguy *et al*. 2011; J. Mainguy, pers. comm. 2012.)

Hibernaculum	Winter 2007/08	2008/09	2009/10		2010/11	2011/12		% Change since WNS detection
	Late	Late	Early	Late	Late	Early	Late	
Halifax	95	92	195				0	-100
Mine-aux-Pipistrelles	524	816		***490***		2		-99
Quebec Copper	537	487	850				0	?
Mine Emerald			74				0	-100
Total	1156	1395	1609			2		-100^

Notes:

1) Abundance based on visual counts. 'Late' = March to April; 'Early' = November to February.

2) Value in bold italics = the survey when WNS was first detected at that site; Halifax and Copper sites likely had WNS in 2009/10. Most sites not surveyed in 2010/11 due to budget constraints.

3) % Change is difference between first detection or year of detection in Quebec (2009/10), and most recent abundance estimate.

4) Partial survey conducted at Quebec Copper in 2012 due to flooding but areas surveyed should have contained bats, as in previous years.

5) Total only includes data from sites that were surveyed across years.

6) Additional sites have been surveyed (e.g. St. Robert Metal, Copperstream Frontenac) but are omitted because data do not extend past arrival of WNS (2009/10).

*^ Regional change is best available data on total of maximum bat number recorded when WNS was detected that year in the region or at a site (1,609 bats; 2009/10), compared with most recent count (2 bats; 2011/12).

The declines recorded for *Myotis* in NB (99%; Table 5) and NS (93%; Table 6) (see *Myotis lucifugus – Canadian Data* section) likely applies to *M. septentrionalis*, based on the following: *M. septentrionalis* are likely, or known, to be present in the hibernacula; 312 (34%) of 919 captures in August 2010 during swarming at Berryton and White caves, and 36 (80%) of 45 captures at Howes Cave in 2011, were *M. septentrionalis* (H. Broders, pers. comm.). Also, 30 (8.4%) *M. septentrionalis* were identified from a sample of 357 dead bats collected at Berryton Cave from a 2011 mass mortality event of 83% of 6,084 bats (McAlpine *et al.* 2011; D. McAlpine, pers. comm.). All three *Myotis septentrionalis* submitted for WNS testing in 2011/12 tested positive (S. McBurney, pers. comm.). In NS, *M. septentrionalis* comprised 28% of 5,974 captures over 11 years at the entrance to the hibernaculum (H. Broders unpub. data). Four carcasses found on the landscape and submitted for testing in 2011-2012 tested positive for WNS (S. McBurney, pers. comm.).

There are no summer data on population size or trends from maternity colonies of *M. septentrionalis* for Canada.

Frick *et al*. (2010a) predicts *Myotis lucifugus* to be functionally extirpated by 2026 (see *Myotis lucifugus – US Data* section). The extension of Frick *et al*. (2010a) to *M. septentrionalis* appears warranted because of the very similar life history characterstics of the two species (see **Morphological Description, Habitat, General Biology** sections) and because both have experienced similar dramatic declines in populations in the northeastern US and Maritimes. Also, Langwig *et al*. (2012) results suggest *M. septentrionalis* populations in the northeastern US are likely to be functionally extirpated (see *Transmission and Risk of Infection* section).

Perimyotis subflavus - US Data

Population declines in infected areas (much of the northeastern US) have been similarly dramatic. Average population decline of *Perimyotis subflavus* in hibernacula for the northeastern US was 76%, as of 2011 (Table 12; Turner *et al.* 2011). Thirteen of 36 hibernacula declined to zero bats. One site (Coon Cave, Virginia), unusual for containing so many *P. subflavus*, declined from 920 bats before WNS, to 112 in 2011 (R. Reynolds, pers. comm.).

Table 12. Abundance of *Perimyotis subflavus* at winter hibernacula in the northeastern United States that had a minimum of two years' exposure to White-nose Syndrome, as of 2011. Adapted from Turner *et al.* 2011, except for data from Maryland (D. Feller, pers. comm.).

State (# sites)	Population Pre-WNS	Population >2 yr Post-WNS	Pre vs Post Difference (%)	# Sites Extirpated
New York (20)	1042	47	-95	9
Pennsylvania (6)	284	28	-90	2
Vermont (5)	15	8	-47	2
Virginia (2)	746	627	-16	0
West Virginia (3)	1020	73	-93	0
Maryland (4)	437	100	-77	1
Total (40)	3544	883	-75	14 (35%)

Summer declines in abundance of *Perimyotis subflavus* are evident where data are available for sites with post-WNS data (Table 13). For example, in NY, in a state-wide, acoustic-based monitoring effort, detection of *P. subflavus* in summer was 0.7 detections/30 km of road in 2009 and declined to 0.4/30 km in 2011. This decline is an underestimate because monitoring was not initiated until severe bat declines from WNS had already taken place (C. Herzog, pers. comm., unpub. data). Also in NY, Dzal *et al*. (2011) found *P. subflavus* bat activity declined from 3.7% of bat passes among seven species, to 1.5%, a 59% decline. Captures of *P. subflavus* from mist netting in NY were rare before WNS (38 total from 737 net nights [0.052] in 2003-2007) and are essentially absent after WNS (3 total from 1,856 net nights [0.002] in 2008-2011) (C. Herzog, unpub. data). Ford *et al*. (2011) noted a decline in late summer versus early summer in bat activity in pre- and post-WNS in northwestern NY, but not when all summer data were combined. In West Virginia, 386 *P. subflavus* were captured pre- WNS (2008) and 101 were captured post-WNS (2010), using the same methodology and capture sites (C. Stihler, pers. comm., unpub. data). Capture rates in West Virginia after WNS (data collected in 2010) were 77% lower than capture rates during a pre-WNS period (1997-2008) (Francl *et al*. 2012). In Pennsylvania, capture rates were 0.005 during summer pre-WNS (55-70 *P. subflavus* with a trap effort of approx. 10-14,000 1 m^2 mesh units set for one hour) and declined to 0.0004 post-WNS in 2010 (13 bats from approx. 31,000 1 m^2 mesh unit) (C. Butchkoski, pers. comm.; Butchkoski 2011). In Virginia, captures at six autumn swarm sites declined from early-WNS levels of 15 *P. subflavus* captures per site to approximately two bats per site in 2011 (R. Reynolds, pers. comm., unpub. data). These data are limited and confined to small areas, but all demonstrate the same trend of significant declines during summer.

Table 13. Summary of abundance indices for *Perimyotis subflavus* derived from various methods in the northeastern United States during the non-hibernation period, before or during early infection of White-nose Syndrome, compared to abundance indices after several years of exposure to White-nose Syndrome.

State	Pre/Early WNS Data (year)	Post-WNS Data (year)	Difference (%)	Source
New York				
Acoustic Survey (northwest)	Avg. 0.7 passes / hr	0.4	-43; not sig. diff.	Ford *et al*. 2011
Acoustic Survey (Albany area)	3.7 % of all bat activity	1.50%	-59	Dzal *et al*. 2011
Mist Netting	0.052 capture rate (2003-2007)	0.002 (2008-2011)	-95	C. Herzog, pers. comm.
Pennsylvania				
Mist Netting	0.005 capture rate	0.0004 (2010)	-92	Butchkowski 2011
Virginia				
Fall Swarm Trapping (5 sites)	Avg. 15 captures pre-WNS	2 (2011)	-87	R. Reynolds pers. comm.
West Virginia				
Mist Netting (effort constant)	386 captured (2008)	101 (2010)	-74	C. Stihler, pers. comm.
Summer Mist Netting (35 sites; same sites and effort)	Avg. 2.3 captures (2005-08)	1.6 (2011)	-30	C. Johnson, pers. comm.
Mist Netting	0.215 capture rate per net night	0.049 (2010)	-77	Francl *et al*. 2012

Perimyotis subflavus - Canadian Data

Results in parts of Canada where WNS has been reported for >2 years are similar to those reported in the US, although the generally low numbers of *P. subflavus* makes it harder to establish if a decline occurred, or animals were missed in a survey (see details below).

In eastern Ontario, *Perimyotis subflavus* were recorded in the monitored hibernacula (*i.e*., 12 at Hunt Mine; L. Hale, pers. comm.) but specific numbers for *P. subflavus* are not available. It is assumed that the 93% decline in *Myotis* indicates a similar mortality level in *P. subflavus*.

In Quebec, 15-21 *Perimyotis subflavus* were recorded in three of 11 hibernacula per year during the two preceding pre-WNS years (Mainguy *et al*. 2011). There are data for only one of the three sites (Mine-aux-Pipistrelles) after the arrival of WNS; the number of *P. subflavus* declined from 17 in March 2010 to one in November 2011, a 94% decline.

In NB, *Perimyotis subflavus* were recorded in five sites (range of 1-9 per site) with a decline from 20 (pre-WNS) to 14 *P. subflavus* (- 30%), and none recorded at three sites in 2011 (D. McAlpine and K. Vanderwolf, unpub. data). Individuals did not show signs of WNS in 2011. A single *P. subflavus* found dead in Berryton Cave in March 2011 and submitted to Atlantic Veterinary College tested positive for *Pd* (S. McBurney, CCWHC unpub. data). In mid-winter 2012/13, Pd spores were first recorded on hibernaculum walls (as distinct from swabs taken from bats), suggesting that Pd spores were then well distributed in hibernacula. By April 2013, the number of *P. subflavus* was five bats (-75% since 2010), and all remaining bats were infected with WNS (D. McAlpine, pers. comm.).

In Nova Scotia, 47 *Perimyotis subflavus* (0.8% of 5,974 total bats) had been captured at the entrance of the five hibernacula being monitored (H. Broders, unpub. data). No carcasses have been found as of winter 2012/13. Based on mortality of *P. subflavus* in adjacent NB, the 91% decline in NS bats in 2012/13 likely includes *P. subflavus*.

Systematic monitoring of summer populations of *Perimyotis subflavus* in Canada has not been conducted.

Rescue Effect

There is no expectation of a rescue effect, given the presence of WNS because: 1) immigrants to previously infected areas likely would not survive; and 2) uninfected subpopulations are expected to become infected. The northern part of *Myotis lucifugus* and *M. septentrionalis* range presently is uninfected but it is unlikely that mortality levels will be different than those recorded southward. Bats in northern hibernacula may hibernate in relatively colder conditions (*i.e.*, 2-3˚C in NT; J. Wilson, pers. comm.) and thus may be less susceptible to WNS because *Pd* does not grow as well at that temperature (Gargas *et al.* 2009). However, bats in laboratories exposed to WNS at <4°C still eventually died (Grieneisen 2011) and the longer period of hibernation in the north will likely result in higher mortality rates. WNS has been spreading into colder regions; to date, the most northerly mortality associated with WNS (*M. lucifugus* and *M. septentrionalis*, 2013) is near Chibougamou, Quebec, 700 km north of Montréal (G. Lupien, pers. comm.).

There is an expectation that mortality levels will be lower in the southern US because infected bats that are forced to look for water and food are likely to find both, and overall hibernation periods are shorter (Hallam and Fedrico 2011; Maher *et al*. 2012). Similarly, the coast of BC is milder and mortality will be lower. However, *Pd* spores persist in soil in hibernacula (see *Transmission and Risk of Infection* section) and it is likely that any bat subpopulations expanding northward from the southern US, or eastward from BC, would be impacted by *Pd* when they enter infected hibernacula in Canada.

Although evidence to date is lacking, if the population develops resistance to WNS (see *Resistance* section), and *Pd* spores are not viable indefinitely (see *Transmission and Risk of Infection* section), then the long-distance movements that helped spread WNS could also facilitate rescue.

THREATS AND LIMITING FACTORS

Number of Locations

WNS constitutes the single most serious and plausible threatening event for the three species. Six years post-arrival, most known hibernacula in the northeastern US and the Maritimes have experienced massive declines. Hibernacula conditions are similar across the range of each species in Canada and at present there is no evidence that WNS will not grow in western caves. A single location could apply. However, the IUCN/COSEWIC guidelines on locations is based on the main threatening event rapidly affecting all individuals, which to date has not occurred for the two *Myotis* species. Therefore, the number of locations at present would instead be ‘many’ for the two *Myotis*, because each hibernaculum or maternity colony across the species’ range presently is subject to varying risk of extermination or disturbance from recreation, mining, etc. For *Perimyotis subflavus*, on the other hand, a single location is plausible because most of the Canadian range of the species is already coincident with the range of WNS within a three-year period.

White-nose Syndrome

Cause and Impact on Bats

Small-bodied bat species that winter in caves or mines are dying from WNS, caused by a dermatophyte fungus, *Pseudogymnoascus destructans* (Minnis and Lindner 2013) (previously called *Geomyces destructans*), believed to have originated in Europe (Lindner *et al*. 2011; Pikula *et al.* 2012; Ren *et al*. 2012; Warnecke *et al.* 2012). It was first detected in North America (NA) in 2006 (Lorch *et al.* 2011) and there is no evidence that the fungus was present in NA prior to this time; *Pd* was absent in samples of soil, walls, and bats in locations prior to the appearance of WNS on bats (Lorch *et al*. 2013; Vanderwolf *et al*. 2013). The fungus grows in cold environments >0°C, with optimum growth between 12-16°C, and no growth >19.8°C (Gargas *et al.* 2009; Blehert *et al.* 2009; 2012, Langwig *et al*. 2012; Verant *et al*. 2012). The fungus grows in the same conditions that the three species inhabit during winter (see **Physiology** section). *Pd* colonizes the bat’s epidermis and damages sweat glands, muscle, connective tissue, blood vessels, and hair follicles (Meteyer *et al.* 2009; Cryan *et al.* 2010). The muzzle often turns white and appears fuzzy while wings and ears have white-gray blotches on the surface (Figure 1; cover of report).

The actual cause of death is under investigation. It is suspected that irritation and dehydration associated with the fungal growth causes bats to arouse from torpor, resulting in increased grooming, premature depletion of fat reserves, and a need to forage for water and food (Warnecke *et al*. 2012, 2013; Brownlee-Bouboulis and Reeder 2013). Large numbers of bats seen flying during winter can be an indicator of WNS. Insect prey generally is absent in winter and bat mortality is hypothesized to be caused by starvation, dehydration, and exposure for those leaving the hibernaculum (Reeder *et al*. 2012; Willis *et al*. 2011; see **Physiology** section). Bats that survive until spring may have damaged wings (numerous holes) and are either too physiologically stressed to successfully birth or feed offspring (Meteyer *et al.* 2009; Reichard and Kunz 2009; Reeder and Turner 2008; Powers *et al.* 2012), or they may die during summer because their immune system reactivates in spring (Bouma *et al*. 2010) and an intense neutrophilic inflammatory response results in cell pathology and death (Meteyer *et al*. 2012). A comparison of pre- and post-WNS changes in reproduction behaviour associated with stress noted shifts in timing and shortening in duration of pregnancy and lactation rates, and the proportion of juveniles of *Myotis lucifugus* were 40% lower, and *M. septentrionalis* 50% lower, when compared to pre-WNS data in West Virginia (Francl *et al*. 2012).

Six species are recorded as dying in significant numbers from WNS: *Myotis lucifugus*, *M. septentrionalis*, *M. sodalis*, *M. leibii*, *Perimyotis subflavus*, and *Eptesicus fuscus* (NWHC 2013). Not all cave-dwelling species appear equally vulnerable; *Eptesicus fuscus* has experienced mortality but some populations may be increasing (Francl *et al*. 2012), possibly because of more active immune systems than other species (Reeder *et al*. 2012). Moreover, *Pd* has been recorded on three additional hibernating species—*M. grisescens*, *M. austroriparius*, and *M. velifer*—but large mortality events have not been observed to date (Foley *et al*. 2011). Five affected species occur in Canada; *M. lucifugus*, *M. septentrionalis*, *M. leibii*, *P. subflavus*, and *E. fuscus*. The species most affected to date in the northeastern US are *M. lucifugus*, *M. septentrionalis*, and *P. subflavus* (Herzog and Reynolds 2012).

WNS was first recorded in February 2006 in Howes Cave near Albany, New York and significant mortality was recorded the following winter (Frick *et al.* 2010a; Figure 5). The prevalence of infected hibernacula was 5% in the second year (2007), then 49 and 59% in the next two years in the northeastern US (Frick *et al*. 2010a). As of fall 2012, it is believed that all known underground hibernacula in the northeastern region of the US are infected with WNS, based on numerous surveys conducted across multiple states as part of the US monitoring program for WNS (Herzog and Reynolds 2012; C. Herzog, pers. comm.). Not all hibernacula have been surveyed but infection has been found in almost all that have been surveyed. For example, in New York, 59 of 100 hibernacula with >10 bats have been surveyed as of 2012, and all are infected (suspected, or confirmed with histopathology). Similar results exist for West Virginia, Virginia, and Pennsylvania where a subsample of the thousands of hibernacula has been surveyed; nearly all were infected (C. Herzog, pers. comm.).

Rate of Spread

The spread of WNS is presented in two stages that recognize positive detection of *Pd* and the actual occurrence of WNS. In the first few years of the outbreak, evidence of WNS was based on the characteristic and externally visible white muzzle (see *Cause and Impact on Bats* section). Since then, PCR-based testing (*i.e.,* Lorch *et al*. 2010) of swabbed bats hibernating in unaffected areas has provided evidence of *Pd* on individuals that lack visible signs of WNS. Based on trends to date, it is believed that these 'positive *Pd*', or 'suspected cases' (Figure 5) likely forecast future declines for the site. In many of the northeastern states, as well as in NS, NB, Quebec, and Ontario, infection and mortality rates were lower (*i.e.*, 20%) in year one of detection, followed by high levels (*i.e.,* >70%) within two years (see below). It is suspected that similar trends are occurring at the western edge of the outbreak. For example, in 2010, *Pd* was recorded at two sites in Missouri but significant mortality events or changes in number of bats per hibernacula had not been detected afterwards. In 2012/13, 11 new hibernacula showed signs of WNS and based on trends in eastern jurisdictions, significant mortality is predicted for next winter (A. Elliot, pers. comm.).

As of September 2013, *Pd*/WNS had been recorded in 23 US states and five Canadian provinces (Figure 5). In some jurisdictions (e.g., NY, NB; McAlpine *et al*. 2011), first detection was coupled with numerous carcasses found in the hibernaculum. Generally, however, bats would be absent from previously populated hibernacula; it is suspected that bats were dying outside hibernacula and not being discovered. WNS was first detected in PEI in February 2013, with 15 confirmed cases as of March 15, 2013 (CCWHC 2013). Additional sites within the existing range of WNS in Canada and the US are being detected each year (e.g., northern NB, central Ontario [Figure 5]), with the most recent (spring 2013) detection of *Pd* in northeastern Minnesota, the first record west of the northern end of the Great Lakes, and 100 km from the Canadian border (MNDNR 2013).

When using data only from sites with known mortality from WNS, the rate of spread was approximately 200-250 km per year in Canada. WNS was first detected in Ontario and Quebec in winter 2009-2010, in NB and NS in 2010-2011, and in PEI in 2012-2013 (Figure 5). The movement rate from the Albany, NY epicentre to NB was 200 km/yr, and 250 km/yr to the westernmost Canadian site (Wawa, Ontario). The first event in Ontario (Cochrane) was 1,000 km from the epicentre (250 km/yr), which may indicate *Pd* can spread in large leaps, either by bat or human movement, or that *Pd* was already present but undetected in Ontario sites that are closer to Albany. When using data from sites with *Pd* (but no evidence of WNS), the rate of spread was more rapid (*i.e.,* 400 km/yr to Missouri; 600 km/yr to Oklahoma; 333 km/yr to Minnesota). Cases of *Pd* or WNS were recorded in eastern Iowa in spring 2012 (268 km/yr) and northern Georgia in March 2013 (215 km/yr).

Transmission and Risk of Infection

The transmission dynamics of WNS within hibernacula are not understood but likely are related to the density of bats and frequency of contact between infected bats and walls, and potentially by people visiting multiple caves (Foley *et al*. 2011).

Laboratory experiments showed bat-to-bat contact spreads *Pd* spores (Lorch *et al*. 2011). The amount of physical contact among hibernating bats varies by species. *Myotis lucifugus* typically roost in clusters, *M. septentrionalis* roost in clusters and by themselves, while *Perimyotis subflavus* typically roost by themselves (see **Adaptability** section). Langwig *et al*. (2012) modelled infection rates and concluded that *M. septentrionalis* populations are not viable in the northeastern US because the density levels and proximity of *M. septentrionalis* within northeastern hibernacula are high enough to facilitate transmission of *Pd* spores. Larger populations of *M. septentrionalis* experienced larger declines than smaller populations but smaller populations still experienced high mortality rates. *M. lucifugus* populations declined, regardless of density, apparently because they cluster in large groups and the transmission of fungal spores continued, even as populations declined. A change in behaviour toward single roosting was noted for this species following the onset of WNS, which may increase the chances of survival. For *P. subflavus*, the modelling by Langwig *et al*. (2012) suggests that <6 *P. subflavus* in a hibernaculum may be below a threshold of risk of transmission. However, the model was based on data as of April 2010 when some hibernacula still had higher survival rates and some caves were uninfected. Now, however, there are no known uninfected, large hibernacula in the northeastern US (Herzog and Reynolds 2012) and results likely would differ.

Recent evidence suggests that contact with infected substrates may be a more significant transmission factor than bat-to-bat contact (Kilpatrick 2013). The amount of physical contact among hibernating bats varies by species, and has not correlated well with infection rates. For example, despite the minimal clustering by *Perimyotis subflavus*, this species has suffered high mortality rates; members of this species existed in low numbers of only several individuals per hibernaculum in NB, but still became infected (see *Perimyotis subflavus - Canadian data* section). It is expected that transmission to uninfected bats will increase as more of the hibernacula surface retains *Pd* spores. There is evidence that the fungus resides in the soil and walls of caves (Chaturvedi *et al*. 2012; Lindner *et al.* 2011; Puechmaille *et al*. 2011), even in summer when bats are absent (Lorch *et al*. 2013). The viability of spores over time is unknown.

Hence, though the dynamics of transmission are unclear, evidence suggests that WNS eventually causes significant mortality in hibernacula with different bat densities, and on species with different clustering behaviour.

At a regional scale, bats themselves are the likely transporters of *Pd*, although more research is needed. Spores of *Pd* have been found on bats during summer, and in bat boxes (Dobony *et al*. 2012) but it is unknown if transmission occurs during summer. Extensive bat-to-bat contact during swarming during autumn may be instrumental in the spread of WNS (B. Fenton, pers. comm.). Swarming behaviour shows young bats where to hibernate and also heralds the start of the mating season; bats may enter caves during swarming (Thomas *et al*. 1979), potentially picking up *Pd* spores from one another.

<u>Infection of Remaining Canadian Range of *Myotis lucifugus* and *M. septentrionalis*</u>

Although there is some uncertainty (see below), *Pd* is expected to continue to spread throughout Canada and the western US because: 1) most of the population of *Myotis lucifugus* and *M. septentrionalis* in the western range hibernates in same range of abiotic conditions found in WNS-affected sites in the east; 2) there is no evidence of containment of *Pd* and WNS events; and 3) bats hibernating in low numbers still appear to be susceptible to WNS (see *Transmission and Risk of Infection* section).

Population declines are expected because most hibernating bats hibernate within the growth range of *Pd* even though there is some variation in both microclimate used by hibernating bats and growth rates of *Pd* at different temperatures (see *Cause and Impact on Bats* section). Based on growing conditions for *Pd* (minimum and maximum temperatures in hibernacula), and the relationship between temperature and lipid reserves in *Myotis lucifugus*, Hallam and Federico (2011) predicted that much of the US has the conditions necessary for growth of *WNS*. Recent suitability modelling based on presence of environmental variables at sites with *Pd* in Europe predicts that all of the current Canadian bat range is susceptible to *Pd*, with highest suitability existing in the Great Lakes region and BC (Puechmaille 2013).

Much of the initial spread of *Pd*/WNS was along a northeast to southwest direction of the Appalachian mountain chain, and northward and eastward into Canada (Figure 5). Infection westward in the US occurred in the Ozark Mountains area and across the Mississippi River in 2011. The disease is approaching less forested regions of central North America but the amount of bat movement along an east-west axis, or from forest to prairie is unknown. The relative dryness, few trees, and hibernacula in the Prairies suggests transmission might occur with less speed across the region, but *Myotis lucifugus* are common in the Prairies (see **Distribution** section) and it is possible that the Prairies would slow, but not prevent, the spread of WNS. Alternatively, WNS may spread westward by routes south and north of the Prairies. The most westerly *Pd* confirmed sites to date (Arkansas, Missouri) are 1,200-1,300 km from the Rocky Mountains (Denver, Colorado), and one possible pathway is for *Pd*/WNS to move northward into Canada after reaching the US section of the Rocky Mountains. To the north, *Pd*/WNS would be expected to move westward across the forested sections of the Prairie provinces because this habitat is similar to forests in infected regions of central Quebec and Ontario, and the Minnesota detection of Pd may be indicative of westward spread. In spite of some evidence of genetic structure (see **Designatable**

Units), enough genetic similarities exist among *Myotis lucifugus* in the Rocky Mountains to suggest that the mountains have not served as a physical barrier to gene flow, and will therefore not prevent WNS from reaching the Pacific Ocean (Russell *et al*. 2012).

If the recorded average rate of spread (200-250 km/yr) is applied under the assumption that the spread will continue at this rate, WNS could occur on the west coast of North America within 12-15 years (*i.e*., 3,000 km from Lincoln County, Missouri to San Francisco, California). Starting from Wawa, Ontario (the most westerly record of WNS in Canada), WNS could reach the BC coast (the western extent of *M. lucifugus*) in 14-17 years at the same rate. The western edge of the Canadian range of *M. septentrionalis* (approximately, Trout Lake, BC to southeastern Yukon) could be reached in 12-15 years. The detection of *Pd* in northeastern Minnesota (800 km west of Wawa) may mean that the fungus is already closer to the Rockies than the Wawa starting point.

In the US, simulation modelling based on dispersal, cave location, climate, and distance predicted that WNS will first reach the Rocky Mountains in 2015 and Pacific coast in 2031 (18 yrs), with the slowest infection along Mexican border (Maher *et al*. 2012). The study did not address Canada because of a lack of data on cave number and location. There is no evidence to suggest different results between Canada and US.

There also is the possibility that WNS will reach western populations faster than the prediction based on the movement of bats. It is suspected that *Pd* was accidently brought to North America by tourists who had visited caves in Europe; the original site of detection was in Howes Cave, a non-commercial part of the Howes Caverns that receives >200,000 visitors per year (Howes Caverns 2013). *Pd* spores have been detected on clothing of people exiting a cave (Okoniewski *et al*. 2010). The possibility of WNS transmission by people raises concern that *Pd* will be transmitted to western hibernacula by tourists or spelunkers who visit multiple sites. The movement of bats from Asia to western North America on ships may also be a conduit for WNS (Wright and Moran 2011).

Limited understanding of the dynamics of transmission increases uncertainty regarding vulnerability of western bats to WNS. The rates of east-west bat movement are unknown, and less is known about hibernating bats in the west than east. There is long-distance, north-south bat movement in Manitoba (see Migration section) but such movement may be atypical, resulting in only a small number of bats present to carry *Pd* (Norquay *et al*. 2013). The number of infected bats required to infect a new site is unknown. Although the site in NT has >3,000 bats, it is suspected that bats in the western range are hibernating at many sites and in small numbers (see **Abundance** section). It is possible, but unproven, that *Pd*/WNS transmission rates could be slower if there are different density- or frequency-dependent factors in western hibernacula that affect the severity of WNS.

WNS and *Perimyotis subflavus*

The impact of WNS on *Perimyotis subflavus* requires additional discussion because the effect of WNS on *P. subflavus* is not as straightforward as it is for the other two species. There are fewer data on *P. subflavus* in Canada than for the other two species and there is some debate on where they hibernate.

Fewer than 30 *P. subflavus* are typically recorded in any US hibernaculum (Fujita and Kunz 1984; Trombulak *et al*. 2001; but see Davis (1959) where 800 *P. subflavus* were banded in two West Virginia caves) and less than 20 in Canada. For Canadian *P. subflavus*, this observation may be because: 1) few exist in Canada during summer and thus there is no discrepancy between winter and summer data sets; 2) more *P. subflavus* actually are present in hibernacula but they are harder to detect; 3) they have migrated southward and winter underground, within WNS range and thus are vulnerable to WNS; or 4) they have migrated southward and are not vulnerable to WNS because they have gone beyond WNS range, or hibernate where WNS is not present (*i.e.*, above ground). In scenario 4, if a significant proportion migrate south (see **Migration** section), and overwinter above ground in southern areas (Davis 1959) it raises doubt as to the severity of WNS on this species (*i.e*., if only a small proportion of the species are in caves, then few are vulnerable to WNS) (B. Fenton, pers. comm.).

There is evidence for the first three scenarios. Records of *Perimyotis subflavus* in summer are very low and similar to the number of winter records (see **Abundance** section). Also, they are believed to be hard to detect in hibernacula; it is suspected that most hibernating *P. subflavus* are in the caves but cannot be seen (A. Hicks, pers. comm. 2011) because they often hibernate singly, and deep in caves where human access is limited (Hitchcock 1949; Fujita and Kunz 1984; Sandel *et al.* 2001).

There is evidence of southward autumnal movement, with distances that could take them into WNS range (northeastern US) and the only records of the species in winter within WNS range are underground. The evidence that *P. subflavus* overwinter above ground anywhere is limited; in Texas, *P. subflavus* hibernate above ground in road culverts (Sandel *et al*. 2001) but 93% of all observation records in the US are in caves or mines (Ellison *et al*. 2003). And the species is considered an obligate hibernator in the US. In Florida, a jurisdiction where insects and temperature may be sufficient to minimize the need for hibernation, *P. subflavus* still hibernate, and are only known from underground caves (McNab 1974).

In summary, evidence suggests that *Perimyotis subflavus* are hibernating underground in Canada, and most likely in the northeastern US within the range of WNS. Importantly, populations in summer show marked decline (see Population Trends section), concurrent with recorded declines in the other bats impacted by WNS; thus it seems likely that *P. subflavus* populations are affected by WNS, regardless of the uncertainty with hibernating behaviour.

In addition, *Perimyotis subflavus* already are a rare species in Canada, and there is evidence that individuals hibernating within WNS range are particularly susceptible. *P. subflavus* hibernate at a temperature that is optimum for the growth of *Pd*, they hibernate for the longest period of time of the three species, and they have essentially no immune activity while hibernating (Raesly and Gates 1987; D. Reeder, pers. comm.). The range of *P. subflavus* in Canada occurs within the present distribution of WNS and refugia are unlikely (Figure 4).

<u>Resistance to WNS</u>

At the early stages of the spread of WNS, it was hoped that only some hibernacula would be vulnerable to WNS. If the spread of WNS was strongly density-dependent, then hibernacula with small populations might escape WNS (Wilder *et al*. 2011). Instead, as of spring 2012, 6-7 winters after first detection, WNS infects virtually all hibernacula in the northeastern US (Herzog and Reynolds 2012; see *Cause and Impact on Bats* section).

A few sites seem resistant to WNS. In Maryland, for example, bats in three abandoned railway tunnels have not shown signs of WNS. These sites have high air flow, fluctuating temperatures, and creosote-covered framing, factors that might inhibit growth of *Pd* (D. Feller, unpub. data). In general, however, these unique and artificial sites contain small numbers of bats and if they persist, likely will not play a significant role in recovery of the regional population.

Hope for any recovery of the species is based on the likelihood that some small percentage of the population across the range will have a genetically based resistance to the effects of *Pd*. These survivors would pass on this resistance to their offspring and populations would increase. It is suspected that such a situation occurred in Europe because even though *Pd* has been recorded on several species of bats, mortality levels are low (Wibbelt *et al*. 2010); in central Europe, 62-64% of 100 hibernacula, and 50% of *Myotis myotis* tested positive for *Pd*, but no mass mortality or aberrant flight behaviour has been recorded (Horacek *et al*. 2012).

There is evidence that some individuals exposed to WNS can survive, based on laboratory data (Meteyer *et al*. 2011) and banding studies (Dobony *et al*. 2011), presumably because the fungus ceases growing as body and ambient temperature increases after bats leave hibernacula (Meteyer *et al*. 2011). In the Dobony study, a small number (*i.e.*, <20) of banded *Myotis lucifugus* in Ft. Drum, NY had wing damage (suggesting exposure to WNS) but had survived and were recaptured the following summer. Five females were recaptured after two years, and some were lactating, suggesting reproduction in some survivors. One cave in NY has populations of approximately 1,000 bats for four years in succession, suggesting stabilization (Turner *et al*. 2011). These results suggest some hope for eventual recovery. It is noted, however, that declines at these sites were 88% (Ft. Drum) and 93% (NY) and apparent stability at some hibernacula may be due to movements of uninfected bats from other areas; lactation does not mean that pups survived if adults are physiologically stressed (Dobony *et al*. 2011). Research designed to evaluate the extent of movement between caves has begun using a large population of banded bats (Hicks *et al*. 2012).

The populations of affected species are not expected to recover quickly because bats have slow population growth rates. Mortality is high in yearlings while adults are long-lived and only produce 1-2 young annually. The population growth rate over 16 years was 1.008 in a recent, pre-WNS study from New Hampshire (Frick *et al*. 2010b), and 0.98-1.2 in 22 populations in the northeastern US (Frick *et al*. 2010a). The rate for *Myotis septentrionalis* and *Perimyotis subflavus* was estimated to be 1.03 and 1.04, respectively (Langwig *et al*. 2012). Such a life-history strategy heightens the vulnerability of these bat species to high adult mortality rates.

Wind Turbines

Turbines cause mortality in bats by direct striking of a bat in flight, or barotrauma associated with acute differences in air pressure near the turbines (Baerwald *et al*. 2008). It is not possible to determine the significance of mortality because total population of the three species is unknown. Also, estimates of mortality are difficult because carcasses are hard to locate due to vegetation, decomposition, scavengers, and size of area to be surveyed (Kunz *et al*. 2007). Regulatory agencies often require a correction factor be applied to the number of carcasses found per site (e.g., OMNR 2011). For example, in one 86-turbine site in southeastern Ontario (Wolfe Island), correction factors estimated that 1,920 bats were killed in one year, based on 118 actual carcasses found (Note: the correction factors are for all species combined but only one of the 118 was identified as either *Myotis lucifugus* or *M. septentrionalis* (Stantec 2010; 2011). Overall, it is not possible to adequately quantify total estimated mortality across the species' range because some data are not available and correction factors are not available by species, or have not been consistently applied or provided.

Long-distance migrant bat species, such as Hoary, Red and Silver-haired (*Lasionycteris noctivagans*) comprised approximately 75-80% of known fatalities at turbines (reviews by Arnett *et al*. 2008; Johnson 2005). *Myotis* bats were not as commonly killed by turbines (e.g., 0-13%; Arnett *et al*. 2008) likely because they migrate shorter distances, and, during summer, generally fly below turbine height (Reynolds 2006). Mortality of *M. lucifugus* in 2010 was estimated at 4,720 bats in 10 northeastern states (Kunz and Reichard 2010).

In Canada, a summary of 1,423 bat carcasses collected from 638 turbines at 16 sites from seven provinces between 2006-2009 (Environment Canada *et al*. 2011) noted nine species, with *Myotis lucifugus* the third most common (21% nationally, 27% in Ontario). Carcasses of *M. septentrionalis* and *Perimyotis subflavus* were found the least, but numbers were not provided. Correction factors that estimate actual mortality were not provided in the review.

Low numbers of *Myotis lucifugus*, and virtually no *M. septentrionalis* and *Perimyotis subflavus*, carcasses have been collected in Canadian jurisdictions: NS (1 *M. lucifugus* from two sites in 2011; M. Elderkin, pers. comm.), NB (4 *M. lucifugus* of 7 total bats at two sites in 2011; M. Sabine, pers. comm.), Manitoba (1 *M. lucifugus*, 0 *M. septentrionalis* from 98 total bats from four turbines at 63 turbine sites over a three-year period; Jameson and Willis 2012); Saskatchewan (0 *Myotis* of 85 bats, Golder 2008; 2 *M. lucifugus* of 46 bats, Golder 2011). In PEI, 9 *Myotis* (6 *M. lucifugus*; remainder too decomposed) were killed at four turbines near Summerside in 2010, suggesting a corrected mortality rate of 2.47 bats/turbine/year (Fundy Engineering 2012). Of 62 carcassses collected from 2005-2011 at six wind farms on the Gaspé Peninsula, Quebec, there were 6 *M. septentrionalis*, 1 *M. lucifugus*, and 0 *P. subflavus* (A. Massé, pers. comm.). In Alberta, neither *Myotis* typically is recorded (Baerwald 2008; R. Barclay, pers. comm.). In BC, *Myotis* (numerous species combined) comprised 44% of fatalities at the first wind development in the province (Hemmera 2011).

Although migratory bats are most vulnerable, there is evidence that relatively large numbers of *Myotis* are killed at some sites, indicating that siting of wind turbines is an important factor in assessing their threat (Arnett *et al*. 2008). A few sites in Tennessee and West Virginia recorded *Perimyotis subflavus* to represent as much as 25% of mortalities, and *Myotis lucifugus* in one site in Alberta as 23% of total mortalities (Arnett *et al*. 2008). In Ontario, *M. lucifugus* comprised 4-60% of mortalities at 16 sites monitored between 2006-2010, and 306 (27%) of 1,133 total bats from nine sites (474 turbines) (Environment Canada *et al*. 2011). An estimated 7,000 *M. lucifugus*, 310 *M. septentrionalis*, and 52 *Perimyotis subflavus* were killed annually, based on correction factors and data from 44 wind farms (2,955 turbines) across Canada (R. Zimmerling, pers. comm.).

Migration distance and proportion of a population that migrates are important factors but we know little of the extent of movement within Canada, or by Canadian bats into US jurisdiction. Most mortality documented in Canada has occurred in August, which corresponds to migration (Johnson 2005). Movement by *Myotis lucifugus* has been recorded between Ontario and NY (Davis and Hitchcock 1965; Fenton 1970a) but the impact of any increase in wind turbines in the US is unknown.

A significant increase in the number of wind farms in North America is expected. The US Department of Energy forecasts 241 GW will be needed to meet their goal of 20% energy from wind by 2030; as of March 2010, the total online was 36 GW (Kiesecker *et al*. 2011). The Canadian Wind Energy Association estimates Canada presently has 5,403 MW (approximately 3,063 turbines) with as many being constructed again in the next five years; Ontario alone is proposing increasing capacity by 5,600 MW by 2018 (CWEA 2012).

Predicting the impact of turbines to bats in the future is confounded by potential mitigation activities. In Ontario, for example, turbines are turned off when mortality levels exceed certain thresholds (McGuiness *et al*. 2011) and since most bat strikes occur during low wind speed, there may be an economic threshold on power generation that also minimizes bat mortality (Baerwald *et al*. 2009).

In summary, mortality levels from wind turbines are unknown because only a small subsample of turbines have been sampled, the number of mortalities varies by location, height, and speed of turbine, and correction factors are of mixed application. Moreover, total bat population size is unknown, making it impossible to assess population-level impacts. Where data exist, evidence to date suggests mortality levels at a national scale are relatively low for *Myotis septentrionalis* and *Perimyotis subflavus*. Mortality levels of *M. lucifugus* can be high in certain locations and total mortality likely will increase with proposed increases in the number of wind farms. Because mortality levels will vary depending on location it is not possible to assess the extent of the threat on each species. The impact of additional mortality from wind turbines on bat populations already decreased by WNS is unknown.

Colony Eradication

Some maternity colonies of bats in buildings are exterminated due to fears of contacting histoplasmosis and rabies, and because of noise and the accumulation of feces. The number of exterminations in Canada is unknown, but likely in the hundreds; a dozen requests are made annually in the Yukon alone (T. Jung, pers. comm.). Most data are anecdotal (e.g. 30,000 exterminated in a Quebec church in mid-1980s; Wells 1986). Colony removal can be significant to local populations because maternity colonies often contain most of the breeding females and offspring for a large area. For example, the only known colony on PEI was in a house and all bats were removed (Brown *et al.* 2007). If maternity colonies have multiple roosts, such as in the Yukon (B. Slough and T. Jung, unpub. data), exclusion from one colony could be mitigated by moving to the other colony.

Eradication programs used chemicals (*i.e.*, dichlorodiphenyltrichloroethane [DDT]) on maternity and overwintering populations in much of the species' southern range (Geluso *et al*. 1976). Pesticides (chlordane and DDT) applied to a New Hampshire maternity colony of *Myotis lucifugus* caused approximately 50% mortality in newborns and decreased the population, but did not eradicate it (Kunz *et al*. 1977). At 11 sites in Ontario, small colonies of *Eptesicus fuscus* were eradicated with DDT, but larger ones persisted (Barclay *et al*. 1979). DDT was commonly used to control bats in Ontario, at least through 1978 (Barclay *et al*. 1979).

Non-lethal methods involve sealing the entrances to a maternity colony to restrict access before females arrive, or after pups have dispersed. Sealing entrances proved the most successful method, as compared to application of DDT and sticky deterrants (Barclay *et al*. 1979). Sealing entrances may cause abandonment of the area, and not just the maternity colony; Neilson and Fenton (1994) found breeding females abandoned the study area when their site was sealed and did not use available bat houses, or move to other nearby maternity colonies in a complex of buildings. Data are unavailable on the extent of non-lethal versus lethal removal in Canada. The closing of abandoned mines also may be a threat to bats if the site was a hibernaculum and most local bats had switched from natural hibernacula to the mine. In some jurisdictions (*i.e.,* Ontario), swarming bat surveys are conducted at sites to be closed (P. Davis, pers. comm.) but the number of mines containing bats that have been sealed is unknown.

Disturbance of Hibernating Bats

In eastern (and possibly western) North America, bat species that hibernate are at risk because most of the population overwinters in only a few sites (see Space Use section) and a high proportion of the population could be affected by single events. Bats enter the hibernation period with a finite fat reserve and a considerable amount of fat is consumed every time they are aroused (see **Physiology** section). Handling of hibernating bats will result in arousal from torpor (Speakman *et al.* 1991) and even without touching them, visitation by people causes arousal; in one study, bats flew above normal rates for up to eight hours after visits that had been <2 hours in length (Thomas 1995). When in deep torpor, bats are generally unaffected by ambient noise (Harrison 1965) but it appears that some individuals are closer to arousal and are the first to respond to noise and light, and begin to fly. Their tactile activities (*i.e*., attempted copulation, rejoining the cluster of bats) causes a cascade of arousal that can result in additional flying bats (Thomas 1995). Frequent and extended visits increase the severity of fat consumption; if the number of arousal events exceed natural rates, bats will consume fat reserves and die (Gaisler *et al.* 1981). Repeated visits over several days likely have severe impacts (Boyles and Brack 2009). Body mass of *Myotis sodalis* was lower at sites with increased levels of human visitation (Johnson *et al*. 1998) and *M. velifer* were disturbed the most from hibernation when tour groups were close, loud, and used lights (Mann *et al*. 2002). Restricting access and the enforcement of these regulations appeared to explain the increased number of *M. lucifugus* documented at Cadomin Cave in Alberta (Olson *et al.* 2011).

Visitation to hibernacula is not recommended (Hutson and Mickleburgh 1988) and some caves and mines are gated to limit liability from injury, but also to minimize disturbance of bats (Sherwin *et al.* 2009). Bats may avoid gated hibernacula and gates and barriers can be a problem for hibernating bats if airflow is restricted (Richter *et al*. 1993). Maintaining gates is a problem in some sites because people repeatedly remove them to gain access. Visitation to caves occurs in four categories; tourists, spelunkers, partiers, and researchers. Most of the visitation occurs in the summer and likely has relatively less impact on bats because they can replenish fat reserves, or are not using the site during summer. The number of visits in winter is unknown for any hibernacula in Canada. Many jurisdictions have local spelunking societies, and webpages identifying cave location and characteristics, as well as guidelines to minimize spread of WNS (e.g., US National Speleological Society). Prior to WNS, bat researchers were required to minimize the number of visits and duration, either though ethical code of practice or university animal care and government permit guidelines. Since WNS, researchers in US and Canada are expected to follow government protocols (USFWS 2012), which include single-use hazardous material coveralls, and fungicide application to equipment and clothing. In summary, the role of people in the spread of WNS within North America is a potentially significant issue but the impact has not been quantified.

Habitat Loss

Habitat for bats is composed of winter hibernacula, foraging habitat, and summer roost and maternity colony structures (see **Habitat** section). The use of buildings and bat boxes for maternity colonies by *Myotis lucifugus* may represent a benefit to the population, but likely less so in remote parts of their range where natural roosts may predominate. The forest structures most associated with maternity colonies for *M. septentrionalis* are numerous, difficult to identify, and have not been inventoried. Declines in amount of older age class forests (i.e., late successional, ‘old-growth’) could be a threat if these forests are preferentially used for foraging and roosting. Alternatively, clearcut harvest creates edge habitat that is widely used for foraging, and forest harvest practices that create forest remnants in harvest area, retain snags, and involve partial cut harvest may mitigate impacts of forestry. Overall, the extent of habitat loss (or gain) cannot be quantified because of the species’ large range and the varied intensity of forest harvest and practices across the range. The intensity and extent of this threat is unknown.

Chemical Contaminants

The threat of contaminants is threefold: direct impact on physiology of the bat either through intake of contaminated food, mortality from eradication programs (see **Colony Eradication** section), and indirectly through reduction of a food source. Toxic levels of organochlorines (*i.e.*, dieldrin, polychlorinated biphenyl, DDT, DDE) derived from insect pest spray programs have been recorded in organ tissue in several species of bats (Reidinger 1976) and shown to cause fatality in fetuses and newborn *Eptesicus fuscus* (Clark and Lamont 1976). Lukens and Davis (1964) determined bats likely are more sensitive to DDT than other mammals. Geluso (1976) demonstrated mortality in young bats that metabolized fat containing toxic levels of DDT and surmised drastic declines in *Tadarida brasiliensis* were due to agricultural use of pesticides. The application of some of these chemicals has declined or been banned (*i.e*., DDT) but the impact of pesticides that remain in use today is not well studied.

Few studies have been made on the impacts of heavy metals on bats but one study in Ontario and Quebec (Hickey *et al*. 2001) found elevated levels of mercury, zinc, selenium, and lead in *Myotis lucifugus*, and mercury and zinc in *M. septentrionalis*. The levels of mercury were high enough to cause sub-lethal biological effects. Bats were likely ingesting heavy metals by feeding on insects (*i.e*., Trichoptera) that emerged from metal-laden sediments in agricultural areas.

The impact to bats from decreases in insects due to pesticide spraying is unknown. Bats consume a wide range of insects over wide areas; a localized application for a short period likely does not impact a population. Widespread and continuous application of pesticides likely would be a significant impact. In much of forested regions of Canada, forest Lepidopterans often are controlled with a naturally occurring bacteria, Bt (*Bacillus thuringiensis*) that kills all Lepidopteran species at a certain larval development stage; the impact on bats is unknown.

Other Threats

Frick *et al*. (2010b) concluded that annual female survival declined because of drier summers, suggesting climate change may be a concern if the amount of summer precipitation declines. Precipitation is associated with insect production, and lower insect abundance would affect a female's ability to recover from producing pups and accumulate fat reserves needed to survive hibernation. Data on bat response for much of the range are unavailable.

The impact of mining activities, during exploration and extraction stages, may be a concern if noise and vibration disturb hibernating bats (N. Gougeon, pers. comm.). Closure of mines that excludes bats or reactivation of abandoned mines containing hibernating bats represents habitat loss. However, data on the extent of such activities are unavailable and the significance of any activity is unknown because the total number of hibernacula or bats is unknown.

Noise from road traffic will cause foraging bats to alter travel routes, and thus increased road density presumably decreases foraging area (Bennet and Zurcher 2012). The severity is not known and much of species' range is in relatively roadless areas.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Until recently, both *Myotis* were relatively common throughout much of their range and protection within many jurisdictions was limited to basic protection as a recognized wildlife species. Many mines have been closed, and the use of gates to allow bat access is variable. The construction of gates is most associated with sites where the presence of endangered species, such as *Myotis sodalis*, has been established. Permits are required in some jurisdictions for pest control activities at maternity colonies. Some protection for the species is derived from shared use of sites that are mainly protected for endangered cave bat species in the US, such as *Myotis sodalis* and *M. grisescens*.

The three species had not been previously assessed by COSEWIC before the 2012 emergency assessment, and a listing decision by the Minister is pending, as of this writing (see Preface section). *M. lucifugus* and *M. septentrionalis* in Ontario were listed as Endangered in January 2013 (OMNR 2013) and those species, plus *P. subflavus*, are in the process of being listed in Quebec (N. Desrosiers and I. Gauthier, pers. comm.). All three species were listed as Endangered in NB in June 2013 (M. Sabine, pers. comm.) and were added to to the list of animals and plants protected under the Nova Scotia *Endangered Species Act* in July 2013.

Following petition and preliminary review, *M. septentrionalis* was added to the US *Endangered Species Act* in October 2013 (Federal Register 2013). A petition was made for emergency listing of *M. lucifugus* in 2010 (Kunz and Reichard 2010) and an assessment process by the US Fish and Wildlife Service is underway (K. Tinsley, pers. comm.). Information requests have been initiated as the first part of an assessment process for *Perimyotis subflavus* (K. Tinsley, pers. comm.).

In 2009-2010, as part of a national response to minimize the spread of WNS, caves in numerous national forests in western US and all caves in the National Wildlife Refuges system were closed to the public (Kunz and Reichard 2010). Numerous states have similar programs established. An extensive research program is underway in the US to document the biology of WNS and mitigation strategies.

Non-Legal Status and Ranks

NatureServe Canada ranks for *Myotis lucifugus* are N3, and N2N3 for *M. septentrionalis*. National rankings had been N5 and N4 for *M. lucifugus* and *M. septentrionalis*, respectively, and were changed in September 2012 due to concerns of WNS. Ranks for *Perimyotis subflavus* are N2N3 (assessed January 2012). *P. subflavus* occurs in four Canadian jurisdictions, with ranks of S1? To S3?. *M. lucifugus* and *M. septentrionalis* are found in most Canadian jurisdictions and generally were ranked as secure (S4 or S5) until recent reviews related to WNS resulted in imperiled status (S1) in NS, NB, and Quebec (Table 14). In PEI, both species were already at high risk status. Outside of WNS range (Table 15), both species are ranked as secure, except in NT and Yukon, where they are ranked S1S2 because of small presumed numbers, and existence at the northern edge of the species' range.

Table 14. Sub-national NatureServe ranks for jurisdictions that have evidence of White-nose Syndrome (suspected or confirmed), with comments on recent changes to status, as of March 2013. Ranks based on NatureServe Explorer (2013) and correspondence with database managers, 2012. Definitions of rank: 1 = Critically Imperilled; 2 = Imperilled; 3 = Vulnerable; 4 = Apparently Secure; 5 = Secure; SNR = unranked; SU = unrankable; B = breeding; N = non-breeding.

Jurisdictions with White-nose Syndrome	Rank			Date Assessed	Comments and Source (pers. comm.)
	Myotis lucifugus	***Myotis septentrionalis***	***Perimyotis subflavus***		
Alabama	S3	S2	S5		no response to information request; WNS in 2012
Arkansas	S3	S4	S5		WNS confirmed in January 2013
Connecticut	S5	SU	S4		review pending due to WNS (K. Zyko)
Delaware	S5	SU	S4		review pending due to WNS; likely S1 (H. Niederriter)
Georgia	S3	S3S4	S5		WNS recorded winter 2012/13
Illinois	S5	S4	S5		WNS recorded winter 2012/13
Indiana	S4	S3	S4	1987	Species of Special Concern (R. Hellmich)
Iowa	S4	S4	S4		WNS confirmed in spring 2012
Kentucky	S5	S4	S4		no response to information request
Maine	S5	S4	SU		potential listing *Endangered Species Act* (J. DePue)
Maryland	S5B, S5N	S4B,S4N	S5B,SUB		review pending due to WNS (D. Feller)
Massachusetts	S5	S4	S3		review pending; Endangered (S. Haggerty)
Minnesota	SNR	S3	S3		WNS confirmed in August 2013
Missouri	S4	S4	SNR	1992	review pending due to WNS (D. Butler)
New Brunswick	S1	S1	S1		change from S4, S4, S2? due to WNS (M. Sabine)
New Hampshire	S5	S3	S1N,SUB		review pending due to WNS (D. Kent)
New Jersey	S5	SU	SU		no response to information request
New York	S5	S3S4	S3	early 1990s	review pending due to WNS (C. Herzog)

Jurisdictions with White-nose Syndrome	Rank			Date Assessed	Comments and Source (pers. comm.)
	Myotis lucifugus	*Myotis septentrionalis*	*Perimyotis subflavus*		
North Carolina	S4	S3S4	S5		no response to information request
Nova Scotia	S1	S2	S1?	April 2012	change from S4 due to WNS (J. Klymko)
Ohio	SNR	SNR	S3?		changing to Species of Concern (G. Schneider)
Oklahoma	S1	S2	S4	1993	(T. Fargin)
Ontario	S4	S3	S3?	2010	(M. Oldham)
Pennsylvania	S1	S1	S1		review pending due to WNS (D. Brauning)
Prince Edward Island	S1	S1S2	n/a	April 2012	was S1 due to hibernacula, plus WNS (J. Klymko)
Quebec	S1	S1	S1	winter 2013	change from S2, S5 due to WNS (N. Desrosiers)
Rhode Island	S5	S2	S4		(D. Gregg)
South Carolina	S5	S5	SNR		
Tennessee	S5	S4	S5	2000	review to be discussed (D. Withers)
Vermont	S1	S4S5	S2S3	2010	change from S5 due to WNS; Endangered (S. Darling)
Virginia	S5	S3S4	S5		review pending (R. Reynolds)
West Virginia	S3	S3S4	S5	2010	*M. lucifugus* changed from S5 due to WNS (M. Welch)

Table 15. Sub-national NatureServe ranks for jurisdictions that have not reported evidence of White-nose Syndrome (suspected or confirmed). Ranks based on NatureServe Explorer (May 2012) and correspondence with database managers, 2012 (see Table 13 for definition of ranks).

Rank	*Myotis lucifugus*	*Myotis septentrionalis*	*Perimyotis subflavus*
S1			Nebraska
S1S2	Northwest Territories	Northwest Territories	
S1S3		Wisconsin	Wisconsin
S2	Mississippi	Kansas	Michigan
S2S3	California	Alberta, British Columbia, Newfoundland	
S2S4	Wisconsin		
S2N, S5B	Manitoba		
S3	Nevada, South Carolina	South Dakota, Yukon	
S3B, S3N?		Mississippi	
S3S4	Kansas		
S3S4N		Manitoba	
S4	Alaska, Montana, Nebraska, Oregon, Utah, Washington DC, Labrador, Newfoundland	Nebraska	Kansas, Washington DC
S4B, SNRN		Saskatchewan	
S4S5	Washington, Yukon		Louisiana

Rank	*Myotis lucifugus*	*Myotis septentrionalis*	*Perimyotis subflavus*
S5	Alberta, British Columbia, Colorado, Idaho, Michigan, New Mexico, South Dakota, Wyoming		Mississippi, Texas
S5B, S5M	Saskatchewan		
SNR	Florida, North Dakota	Michigan	Florida
SU		North Dakota	
SH		Florida	

The global NatureServe ranks were changed from a status of secure-apparently secure (G5, G4) in July 2012 due to WNS and are now ranked as G3 (vulnerable) for *Myotis lucifugus* and *Perimyotis subflavus*, and G1G3 (critically imperiled to vulnerable) for *M*. *septentrionalis*. The US national rank for the three species changed from N5 (secure) to N3 (*M. lucifugus*, *P. subflavus*) and N1N3 (*M. septentrionalis*). Most jurisdictions within the range of WNS rank the three species as Secure (S5) or Apparently Secure (S4) but status is changing; of the 15 jurisdictions within the range of WNS that responded to a request for an update on their ranking process, 13 jurisdictions are reviewing the status due to WNS (Table 14). Several states recently have listed one or all three species as endangered (e.g., Massachusetts, Vermont) or threatened (Wisconsin), or are in the process of a review that may result in listing under some higher category of risk (e.g., Maine, Maryland, Ohio). NatureServe ranks for jurisdictions beyond WNS range are presented in Table 15.

Perimyotis subflavus is found in four jurisdictions, and each of their ranks indicated some concern (e.g., S2?, S3? status) existed for the species before WNS. In 2012-2013, NS, NB, and Quebec uplisted the species to S1?, S1, and S1 respectively, due to WNS (Table 14).

A national strategy for coordinating the management of and response to WNS in Canada is under development (Inter-agency WNS Committee 2012). The strategy parallels the American plan and includes goals for communication to the public and decision-makers about WNS, standardized monitoring, diagnostics, database management, and conservation practices.

Habitat Protection and Ownership

Protection levels vary across Canada. Bats are listed as wildlife under provincial wildlife acts, (except for PEI; R. Curley, pers. comm.), and cannot be hunted or harmed without permit. Some jurisidictions allow the removal of colonies on private property. Known hibernacula may have special protection related to development and resource extraction (*i.e*., in Manitoba, a 200 m radius buffer from forest harvest is required; Manitoba 2010; in NF, development is restricted within 200 m of the main large hibernaculum; S. Moores, pers. comm.). A policy requiring surveys to determine presence of bats in mines scheduled for closure does not exist in most jurisdictions. Jurisdictions have begun to respond to WNS by restricting access and/or recommending that the public stay out of hibernacula and avoid using the same clothes and equipment if travelling to multiple sites. For example, in NS, all mines on public land are off-limits due to safety concerns, as are several natural caves, one of which (Hayes Cave) is the main provincial hibernaculum. Four sites are gated (M. Elderkin, pers. comm.). In NB, one site has restricted access because it is in a protected natural area (M. Sabine, pers. comm.). The main hibernaculum in Manitoba (St. George Cave) is a protected ecological reserve (Dubois and Monson 2007). Some jurisdictions outside WNS range have restricted access as a precaution; hibernating bats in Cadomin Cave, Alberta, for example, have been protected from disturbance with the Alberta *Wildlife Act* since 1984 but the site remained heavily visited and was closed year-round to the public in May 2010 (Olson *et al*. 2011). The efficacy of restrictions in limiting the spread of WNS is unknown. Many known hibernacula in southern parts of the Canadian range are on private land where restrictions may not apply. The hibernaculum in NT is on Aboriginal property.

Ownership of habitat is not as significant an issue because these wide-ranging species are found in a variety of urban, rural and forest landscapes, and overwintering in hundreds of hibernacula. Southern hibernacula could be at risk on private lands if restrictions did not apply and landowners impacted the site. The species are found in most national and provincial protected areas within their range. Hibernacula are located on private, public, and Aboriginal property. Protection of the species resides with multiple landowners.

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COLLECTIONS EXAMINED

No collections were examined.

Appendix 1. Issues with Data

Population trend data are derived from two periods (overwintering and summer), with the majority of data from the overwintering period. Most winter data are of counts of bats in hibernacula, but not all hibernacula are monitored. *Perimyotis subflavus* are relatively easy to identify because of their size and colour (Tuttle 2003). The separation of *Myotis* species by sight is more difficult; *Myotis septentrionalis* and *M. lucifugus* can be separated based on the pointed tragus of *M. septentrionalis*, but only if they are near (e.g., <1 m, such as in low, flat-ceiling mines). In Quebec and many US jurisdictions, surveyors are confident they can separate the two species at certain sites because of their proximity to bats, and/or use of high-resolution photography (see below). However, there is a lack of consensus among jurisdictions on whether the two species should be combined or separated in surveys. Data on *Myotis* species are combined in Ontario (L. Hale, pers. comm. 2012), New Brunswick (D. McAlpine, pers. comm.) and Nova Scotia (H. Broders, pers. comm.).

The most complete summary of population change in bats in hibernacula impacted by WNS is a compilation of survey efforts by five state agencies (New York, Pennsylvania, Vermont, Virginia, West Virginia) as of winter 2010-2011, using sites with >1 year of post-WNS exposure (Turner *et al*. 2011; G. Turner, pers. comm.). The Turner *et al*. (2011) paper does not list effort (e.g., how species are separated, % of sites surveyed, number of observers, observer training), which makes it difficult to compare surveys. To address this issue, the report author contacted state biologists regarding effort and confidence associated with identifying species in their surveys. In New York, high resolution photography is used to identify *Myotis* to species, in part because of need to identify all endangered *M. sodalis* (C. Herzog, pers. comm.). Some monitoring of bats in the northeastern US has been standardized as part of the American WNS monitoring program, and it was standard practice in Vermont to minimize bias associated with effort, or not include such data (Darling and Smith 2011).

Identifying a species is more difficult as distance from the observer increases. The highest counts for *M. septentrionalis* in the northeastern US sites are in hibernacula with the lowest ceilings, suggesting an increased confidence that data recorded as *M. septentrionalis* are actually correct (C. Herzog, pers. comm.). Assuming that detection probability is constant pre- and post-WNS, and any identification bias is constant, a decline recorded in these sites likely represents an actual decline. In Tables 1, 8, only the sites with low ceilings in Vermont were included for *Myotis* data (S. Darling, pers. comm.).

Although there may be a concern about actual numbers of *Myotis lucifugus* and *M. septentrionalis* in US hibernacula, there is confidence that both species are present in the hibernacula; Griffin (1940a) identified 589 *Myotis septentrionalis* in 10 of 11, and 2,998 *M. lucifugus* in 11 of 11 hibernacula, while banding bats in four northeastern states (Connecticut, Massachusetts, New York, Vermont). Recent data suggest *M. septentrionalis* have maintained a significant presence in the northeast; 41% of 11,734 bats caught in West Virginia between 1998-2007 were *M. septentrionalis* (compared to 25% *M. lucifugus*) (Francl *et al*. 2012) and *M. septentrionalis* were regularly captured throughout the northeast in the last 10 years (Brooks 2009).

Another issue with data on declines is that declines may have resulted from inter-cave movement, rather than mortality. This issue is being studied but the winter declines are considered real because declines in summer mirror declines in winter. Also, accuracy of species identification is not an issue because most summer data comes from captures.

Finally, the issue of species identification is somewhat moot. Both *Myotis* species are present and the decline is so extensive that few, or no bats, remain. As of 2011, in 19 (66%) of the 29 sites where *Myotis* data were separated into *M. lucifugus* or *M. septentrionalis*, populations declined to <50 bats, and in six sites (21%), populations declined to zero bats (Turner *et al*. 2011). Additional sites have been infected and declines continue. Declines in the Maritimes have been as extensive as in the US northeast. In summary, even though exact numbers of each species are debated, the issue of species identification is at least partially addressed and much data on *M. septentrionalis* in Turner *et al*. (2011) clearly reflects observed trends. A compilation of population counts by hibernaculum is in development but to date does not include post-WNS data (BPD 2013).