COSEWIC
Assessment and Status Report

on the

Hoary Bat *Lasiurus cinereus*
Eastern Red Bat *Lasiurus borealis*
Silver-haired Bat *Lasionycteris noctivagans*

in Canada



ENDANGERED
2023

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. 2023. COSEWIC assessment and status report on the Hoary Bat *Lasiurus cinereus*, Eastern Red Bat *Lasiurus borealis* and Silver-haired Bat, *Lasionycteris noctivagans*, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxi + 100 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Production note:
COSEWIC would like to acknowledge Erin Baerwald, Robert Barclay, Mark Brigham, Dana Green, Thomas Jung and Cory Olson for preparing the status report on the Hoary Bat (*Lasiurus cinereus*), Eastern Red Bat (*Lasiurus borealis*) and Silver-haired Bat (*Lasionycteris noctivagans*) in Canada. This status report was overseen and edited by Stephen Petersen, Co-chair of the COSEWIC Terrestrial Mammals Specialist Committee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Chauve-souris cendrée (*Lasiurus cinereus*), Chauve-souris rousse de l'Est (*Lasiurus borealis*) et la Chauve-souris argentée (*Lasionycteris noctivagans*), au Canada.

Cover illustration/photo:
Hoary Bat (left) by Jason Headley, Eastern Red Bat (middle) by Robert Barclay, and Silver-haired Bat (right) by Jason Headley.

Catalogue No. CW69-14/829-2023E-PDF
ISBN 978-0-660-49505-7

COSEWIC
Assessment Summary

Assessment Summary – May 2023

Common name
Hoary Bat

Scientific name
Lasiurus cinereus

Status
Endangered

Reason for designation
This large-bodied bat has light yellow-brown fur on its face and neck and white tipped hairs over most of its body. It is found across Canada in the summer months and during fall migration. Seasonal migration exposes individuals to a variety of threats including a high risk of mortality at wind energy facilities. Although there is considerable uncertainty regarding the exact rates of decline for these bats across Canada, declines in carcass counts at wind energy facilities suggest declines far in excess of 50% over three generations. The planned increase in wind power capacity will increase this threat but mitigation is possible. Population viability modeling estimates the probability of extinction is least at the 20% threshold by 2050 (3 generations). Additional threats to this species include ongoing and widespread declines in insect abundance, loss of forested roosting and foraging habitat, and pollution.

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

Status history
Designated Endangered in May 2023.

Assessment Summary – May 2023

Common name
Eastern Red Bat

Scientific name
Lasiurus borealis

Status
Endangered

Reason for designation
This medium sized reddish-orange bat is found across most of Canada in the summer months and during its fall migration. This bat migrates annually, and this seasonal migration exposes individuals to numerous threats, of which the greatest is from mortality at wind energy facilities. Although there is considerable uncertainty regarding exact rates of decline for these bats across Canada, declines in carcass counts at wind energy facilities suggest declines far in excess of 50% over three generations. The planned increase in wind power capacity will increase this threat but mitigation is possible. Additional threats include habitat loss and degradation, habitat change and pesticide use, and widespread declines in prey insect abundance.

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

Status history
Designated Endangered in May 2023.

Assessment Summary – May 2023

Common name
Silver-haired Bat

Scientific name
Lasionycteris noctivagans

Status
Endangered

Reason for designation
This large-bodied bat has black to dark brown fur often with silver or grey tips and is found across Canada in the summer months and during fall migration. Some individuals overwinter in British Columbia and southern Ontario, however most migrate out of Canada annually. This seasonal migration exposes individuals to a variety of threats including risk of mortality at wind energy facilities. Although there is considerable uncertainty regarding the exact rates of decline for these bats across Canada, declines in carcass counts at wind energy facilities suggest declines far in excess of 50% over three generations. The planned increase in wind power capacity will increase this threat but mitigation is possible. Other threats to this species include ongoing and widespread declines in insect abundance, loss of forested roosting and foraging habitat, and pollution.

Occurrence
British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia, Newfoundland and Labrador, Yukon, Northwest Territories

Status history
Designated Endangered in May 2023.

COSEWIC
Executive Summary

Hoary Bat *Lasiurus cinereus*
Eastern Red Bat *Lasiurus borealis*
Silver-haired Bat *Lasionycteris noctivagans*

Wildlife Species Description and Significance

Hoary Bats, Eastern Red Bats, and Silver-haired Bats are medium to large in body size relative to other bats species in Canada, with Hoary Bats being the largest species in Canada. All three species have complex and varied colouration that aids in camouflage while roosting or hibernating. These three bat species are similar in that they mostly roost in trees, migrate long distances between summer breeding grounds and their winter range, are long-lived, give birth to more than one pup per year, and share similar diets and ecomorphology.

There is no evidence of population genetic structure in any of these three species. There is only one designatable unit for each species in Canada.

Distribution

All three species are widely distributed in North America, found from the northern boreal forest to central Mexico. In Canada, the three species have a range that extends from British Columbia to the Atlantic provinces during the summer, although their extent of occurrence in Prince Edward Island and the territories is uncertain. These species migrate seasonally from their northern summer ranges to their southern wintering areas outside of Canada; however, some Silver-haired Bats overwinter in British Columbia and around the Great Lakes.

Habitat

Habitat requirements for these species include foraging, drinking, and roosting habitats, with the latter considered the most limiting. All three species roost in trees; however, Hoary Bats and Eastern Red Bats roost by hanging from branches, and Silver-haired Bats roost in tree cavities or under exfoliating bark.

All three species catch aerial insects while in flight. Foraging habitats vary for all three species but include wetlands, open areas, and edge or gap habitats in forested landscapes.

Biology

All three bat species migrate seasonally. They are relatively fast flyers that hunt most often in open habitats or along habitat edges and within canopy gaps in forested landscapes. They are obligate insectivores that prey on aerial insects.

These species are relatively fecund compared to other bats. They likely first give birth in their second year. Hoary Bats and Silver-haired Bats usually have twins, but Eastern Red Bats may have up to four pups.

Vital rates (survival, longevity, age structure, etc.) are mostly unknown but it is inferred from similar, related species that they are relatively long-lived, with maximum lifespans of at least 12–15 years. Generation time is unknown but estimated to be 2–6 years based on IUCN methodology and inferences for similar bats.

Population Sizes and Trends

The primary means used to assess the relative abundance of bats include mark-recapture studies and emergence counts. However, coordinated North American-wide monitoring for bats (e.g., NABat) has not occurred for long enough in Canada to generate population trend data. Given the limitations, multiple sources of information were used to assess population trends, including carcass searches at wind energy facilities, changes in capture and acoustic detection rates, rabies submission rates, and population viability modelling that relied on expert estimates.

Current population levels for all three species are unknown; however, experts postulated that the most likely population size of Hoary Bats across North America is approximately 2.25 million individuals. Given the similarities in life history and ecology, it was assumed that this estimate can also be broadly applied to Silver-haired Bats and Eastern Red Bats.

In 2007, expert elicitation and projected fatality rates were used to model the effect of wind energy production on Hoary Bat populations in North America. The models were based on variable initial population size, levels of wind energy build-out and fatality rates from the year 2014, along with favourable population growth rates without mortality due to wind turbines. That is, the models only considered additive mortality as a result of fatalities at wind turbines, not other threats. Some plausible models suggested that Hoary Bats will decline by 50% to 90% in the next 50 years, a 1.4% to 4.5% annual decline. The "most likely" demographic scenario predicted that fatalities associated with wind energy facilities would result in a 90% population decline over 50 years, with a 22% probability of extinction over the next 100 years. Follow-up studies that included population models accounting for projected build-out (with/without mitigation to reduce fatality rates) estimated extinction risk at 0–40% by 2050 based on various build-out scenarios with a midpoint of 20%. These results suggest that significant population declines may have already occurred if the initial Hoary Bat population size was below 3 million individuals. Recently, multiple, independently derived genetic estimates of effective population size for all three species across North

America also suggest their current population sizes are well below 3 million. It is expected that similar probabilities apply to Eastern Red Bats and Silver-haired Bats; however, neither of these species has been explicitly modelled.

In support of the decline suggested by population modelling for Hoary Bats, there are multiple lines of evidence to suggest that population declines are occurring in migratory tree-roosting bats including declining capture rates of lasiurine (bats within the genus *Lasiurus*) bats, and a decrease of annual rabies submissions. Change in fatality rates at wind turbines, change in capture and acoustic detection rates, and change in rabies submission rates all suggest declines for all species.

In Ontario, the number of carcasses found under wind turbines during the late summer and autumn migration declined significantly over seven years and recent occupancy modelling in the US Pacific Northwest provides evidence of a decline in the regional occurrence probability of Hoary Bats (2016–2018 relative to 2010). Multi-year acoustic and capture studies also provide evidence for population changes for all three species. In the US, all three species have declined in terms of the proportion of overall bat submissions for rabies testing.

Threats and Limiting Factors

These three bat species face several threats, some of which are common to all bats found in Canada, while others are more specific to these migratory species. Several threats contribute cumulatively to suspected declines for all three species. Based on the IUCN threats calculator, the threats assessment is High to Very High for Hoary Bats, Eastern Red Bats, and Silver-haired Bats.

Wind energy development is the most immediate and concerning threat. Hoary Bats, followed by Silver-haired Bats, and then Eastern Red Bats, account for most fatalities at wind turbines in Canada. The number and extent of wind energy facilities (hereafter "build-out") will continue to increase substantially across the range of these species.

The global decline of insects is of particular concern for these bats, which are obligate insectivores, as it is for migratory birds, which are aerial insectivores. The causes of insect declines are likely multifactorial, cumulative, and difficult to reverse. While long-term abundance data do not exist for migratory bats, they are likely just as affected by widespread declines in prey as birds with similar diets are.

Other threats include chemical and noise pollution, as well as deforestation that results in the loss of roosting habitat. However, these threats are considered to have a low impact over the next three generations for all three species.

Protection, Status and Ranks

None of these bats receive special protection in Canada, except in Quebec where they are included on the Liste des espèces susceptibles d'être désignées menacées ou vulnérables (list of wildlife species likely to be designated threatened or vulnerable). Quebec is also the only province to have established a recovery strategy for Eastern Red Bats. In most jurisdictions, in conjunction with other wildlife, they are provided general protection by provincial and territorial wildlife acts. In 2018, Hoary Bats and Eastern Red Bats were added to Appendix II of the Convention on Migratory Species (CMS) based on their "unfavourable conservation status" related to the rapid expansion of wind energy and the need for international cooperation for their conservation.

All three species are ranked as Least Concern in the IUCN Red List, but key threats identified in this assessment were not considered. In contrast, NatureServe's global status (G ranks) for all three species is G3G4, rounded to G3 (Vulnerable). The national status (N ranks) for all of these bats in Canada by NatureServe is N5B, NUM; that is, the breeding population is assessed as Secure, while the status of the migratory population is Undetermined. The status of each of these three bat species assessed in each province, territory, or state (S ranks) is variable, likely reflecting more about the state of knowledge in each jurisdiction rather than their actual conservation status.

TECHNICAL SUMMARY – Hoary Bat

Lasiurus cinereus

Hoary Bat

Chauve-souris cendrée

Range of occurrence in Canada (province/territory/ocean):
British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, Yukon, Northwest Territories

Demographic Information

Generation time (based on the IUCN Generation Calculator and also uses Pacifici *et al.* [2013] for the upper value of 5.6 [6]) years)	Estimated at 2–6 yrs (3 generations = 6–18 years)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations (6-18 yrs), whichever is longer up to a maximum of 100 years].	Greater than 70% based on multiple lines of evidence (90.5% decline inferred based on observed 21% annual declines in fatality rates over the past 7 years ~1 generation)
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Projected reduction: Greater than 70% based on multiple lines of evidence and threat impacts
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	Suspected to be >70% reduction, based on observed, inferred, and projected mortality
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Partially b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	Unknown but likely ≥ 2,000,000 km²

Index of area of occupancy (IAO) (Always report 2 x 2 grid value).	Unknown but likely ≥ 100,000 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations" * (use plausible range to reflect uncertainty if appropriate)	Well over 10
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Inferred decline in quality of habitat.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	Unknown
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 subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
	Unknown but estimated at 2.25 million in the USA and Canada, with about 50% of those bats plausibly in Canada during summer.
Total	Unknown but likely in the order of 1.13 million mature individuals in Canada during summer

* See Definitions and Abbreviations on COSEWIC website for more information on this term.

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations (10-30 yrs; 30 yrs is 2050) whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Yes. Population viability analysis modelling estimates the probability of extinction at 22% in 100 years. A more recent analysis estimated 0–40% by 2050 based on various build-out scenarios with a midpoint of 20%.

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species?

Yes (13 Aug 2021). Overall threat impact is Very High to High

i. Energy production & mining (IUCN 3) – very high - high impact
ii. Natural system modifications (IUCN 7) – high - medium impact
iii. Pollution (IUCN 9) – medium – low impact
iv. Agriculture & aquaculture (IUCN 2) - low impact
v. Transportation & service corridors (IUCN 4) – low impact
vi. Biological resource use (IUCN 5) – low impact

What additional limiting factors are relevant?

i. Storms and inclement weather
ii. Rarity in local bat assemblages (i.e., low density)
iii. Slow life history (long lifespan, low reproductive output, etc.)
iv. Predation
v. Accidents, especially during migration

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown and variable, but not likely secure.
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada? [+]	Yes
Are conditions for the source (i.e., outside) population deteriorating? [+]	Yes
Is the Canadian population considered to be a sink? [+]	No
Is rescue from outside populations likely?	No. Populations in the US likely face greater severity of threats than those in Canada.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Endangered in May 2023.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** A2be+3be+4be; E
Reasons for designation: This large-bodied bat has light yellow-brown fur on its face and neck and white tipped hairs over most of its body. It is found across Canada in the summer months and during fall migration. Seasonal migration exposes individuals to a variety of threats including a high risk of mortality at wind energy facilities. Although there is considerable uncertainty regarding the exact rates of decline for these bats across Canada, declines in carcass counts at wind energy facilities suggest declines far in excess of 50% over three generations. The planned increase in wind power capacity will increase this threat but mitigation is possible. Population viability modelling estimates the probability of extinction is least at the 20% threshold by 2050 (3 generations). Additional threats to this species include ongoing and widespread declines in insect abundance, loss of forested roosting and foraging habitat, and pollution.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2be+3be+4be. Inferred reduction of >50% although there are uncertainties associated with some assumptions and significant ongoing and future threats.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. The range in Canada exceeds thresholds for both EOO and IAO.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population size is not estimated to be small and exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. Summer range covers a large portion of Canada.
Criterion E (Quantitative Analysis): Meets Endangered, E. Population viability analysis modelling estimates extinction probability to be at least at the 20% threshold by 2050 (30 years or 3 generations).

TECHNICAL SUMMARY – Eastern Red Bat

Lasiurus borealis

Eastern Red Bat

Chauve-souris rousse de l'Est

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

Demographic Information

Generation time (based on the IUCN Generation Calculator and also uses Pacifici *et al.* (2013) for the upper value of 6 years)	Estimated at 2–6 yrs (3 generations = 6–18 years)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Inferred reduction: greater than 70% based multiple lines of evidence. (94% decline over 3 generations inferred from a 27% annual decline in fatalities observed in Ontario data)
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Greater than 70% based on multiple lines of evidence. (suspected 94% decline over 3 generations; based on observed 27% annual decline in fatalities observed in Ontario data)
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	Suspected to be >70% decline, based on observed, inferred, and projected mortality
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Partially b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	Unknown but likely ≥ 2,000,000 km²
Index of area of occupancy (IAO) (Always report 2 x 2 grid value).	Unknown but likely ≥ 100,000 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations" * (use plausible range to reflect uncertainty if appropriate)	Well over 10
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Inferred decline in quality of habitat.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	Unknown
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 subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
	Unknown but estimated at 2.25 million in US and Canada, with about 50% of those bats plausibly in Canada during summer (based on estimates for Hoary Bats)

* See Definitions and Abbreviations on COSEWIC website for more information on this term.

Total	Unknown but likely in the order of 1.13 million mature individuals in Canada during summer

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Not Completed.

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species?

Yes (13 August 2021). Overall threat impact is Very High - High.

i. Energy production & mining (IUCN 3) – high impact
ii. Natural system modifications (IUCN 7) – high - medium impact
iii. Pollution (IUCN 9) – medium – low impact
iv. Agriculture & aquaculture (IUCN 2) – low impact
v. Transportation & service corridors (IUCN 4) – low impact
vi. Biological resource use (IUCN 5) – low impact
vii. Invasive & other problematic species and genes (IUCN 8) – low impact

What additional limiting factors are relevant?

i. Storms and inclement weather
ii. Rarity in local bat assemblages (i.e., low density)
iii. Slow life history (long lifespan, low reproductive output, etc.)
iv. Predation
v. Accidents, especially during migration

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown and variable, but not likely secure.
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada? [+]	Yes
Are conditions for the source (i.e., outside) population deteriorating? [+]	Yes
Is the Canadian population considered to be a sink? [+]	No

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Is rescue from outside populations likely?	No. Populations in the US likely face greater severity of threats than those in Canada.

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Endangered in May 2023.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** A2be+3be+4be
Reasons for designation: This medium sized reddish-orange bat is found across most of Canada in the summer months and during its fall migration. This bat migrates annually, and this seasonal migration exposes individuals to numerous threats, of which the greatest is from mortality at wind energy facilities. Although there is considerable uncertainty regarding exact rates of decline for these bats across Canada, declines in carcass counts at wind energy facilities suggest declines far in excess of 50% over three generations. The planned increase in wind power capacity will increase this threat but mitigation is possible. Additional threats include habitat loss and degradation, habitat change and pesticide use, and widespread declines in prey insect abundance.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2be+3be+4be. Inferred reduction of >50% in index of abundance, although there are uncertainties associated with some assumptions and significant ongoing and future threats.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. The range in Canada exceeds thresholds for both EOO and IAO.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population is not estimated to be small and exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. Summer range covers large portion of Canada.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

TECHNICAL SUMMARY – Silver-haired Bat

Lasionycteris noctivagans

Silver-haired Bat

Chauve-souris argentée

Range of occurrence in Canada (province/territory/ocean):
British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland and Labrador, Yukon, Northwest Territories

Demographic Information

Generation time (based on the IUCN Generation Calculator and also uses Pacifici *et al.* (2013) for the upper value of 4 years)	Estimated at 2–4 yrs (3 generations = 6–12 years)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	
[Observed, estimated, **inferred**, or suspected] percent [**reduction** or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Greater than 70% based on multiple lines of evidence. (94% decline inferred over 3 generations (12 years) based on a 29% annual decline in fatalities observed in Ontario)
[**Projected** or suspected] percent [**reduction** or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Greater than 70% based on multiple lines of evidence. (94% decline over 3 generations (12 years) based on a 29% annual decline in fatalities observed in Ontario)
[Observed, estimated, inferred, or **suspected**] percent [**reduction** or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	Suspected greater than 70% decline based on observed, inferred, and projected mortality
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Partially b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	Unknown but likely ≥ 2,000,000 km²

Index of area of occupancy (IAO) (Always report 2 x 2 grid value).	Unknown but likely ≥ 100,000 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations" * (use plausible range to reflect uncertainty if appropriate)	Well over 10
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Inferred decline in quality of habitat.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	Unknown
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 subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
	Unknown but estimated at 2.25 million in the US and Canada, with about 50% of the bats plausibly in Canada during summer (based on estimates for Hoary Bats)
Total	Unknown but likely in the order of 1.13 million mature individuals in Canada during summer

* See Definitions and Abbreviations on COSEWIC website for more information on this term.

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Not Completed.

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species?

Yes (13 August 2021). Overall threat impact is High.

i. Energy production & mining (IUCN 3) – high impact
ii. Natural system modifications (IUCN 7) – high - medium impact
iii. Pollution (IUCN 9) – medium – low impact
iv. Agriculture & aquaculture (IUCN 2) – low impact
v. Transportation & service corridors (IUCN 4) – low impact
vi. Biological resource use (IUCN 5) – low impact
vii. Invasive & other problematic species and genes (IUCN 8) – low impact

What additional limiting factors are relevant?

i. Storms and inclement weather
ii. Rarity in local bat assemblages (i.e., low density)
iii. Slow life history (long lifespan, low reproductive output, etc.)
iv. Predation
v. Accidents, especially during migration

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown and variable, but not likely secure.
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada? [+]	Yes
Are conditions for the source (i.e., outside) population deteriorating? [+]	Yes
Is the Canadian population considered to be a sink? [+]	No
Is rescue from outside populations likely?	No. Populations in the US likely face greater severity of threats than those in Canada.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Endangered in May 2023.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** A2be+3be+4be
Reasons for designation: This large-bodied bat has black to dark brown fur often with silver or grey tips and is found across Canada in the summer months and during fall migration. Some individuals overwinter in British Columbia and southern Ontario, however most migrate out of Canada annually. This seasonal migration exposes individuals to a variety of threats including risk of mortality at wind energy facilities. Although there is considerable uncertainty regarding the exact rates of decline for these bats across Canada, declines in carcass counts at wind energy facilities suggest declines far in excess of 50% over three generations. The planned increase in wind power capacity will increase this threat but mitigation is possible. Other threats to this species include ongoing and widespread declines in insect abundance, loss of forested roosting and foraging habitat, and pollution.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2be+3be+4be. Inferred reduction of >50% although there are uncertainties associated with some assumptions and significant on-going and future threats.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. The range in Canada exceeds thresholds for both EOO and IAO.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population not estimated to be small and exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. Summer range covers large portion of Canada.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

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
(2023)

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 and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

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

COSEWIC Status Report

on the

Hoary Bat *Lasiurus cinereus*
Eastern Red Bat *Lasiurus borealis*
Silver-haired Bat *Lasionycteris noctivagans*

in Canada

2023

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Mammalia
Order: Chiroptera
Family: Vespertilionidae
Scientific name: *Lasiurus cinereus* (Palisot de Beauvois 1796)
Scientific name: *Lasiurus borealis* (Müller 1776)
Scientific name: *Lasionycteris noctivagans* (Le Conte 1831)

Common Names:

Lasiurus cinereus: Hoary Bat (English) and Chauve-souris cendrée (French).

Lasiurus borealis: Eastern Red Bat (English) and Chauve-souris rousse de l'Est (French). Sometimes shortened to Red Bat (English) or Chauve-souris rousse (French), but this more generally refers to the red bat lineage (subgenus *Lasiurus*), which includes multiple other species (Baird *et al.* 2015; Simmons and Cirranello 2020).

Lasionycteris noctivagans: Silver-haired Bat (English) and Chauve-souris argentée (French).

The taxonomy of the genus *Lasiurus* is under revision. Red Bats and Hoary Bats may constitute either separate genera or subgenera within the Lasiurini (tree bat) tribe (Baird *et al.* 2015; Simmons and Cirranello 2020), but their taxonomic status remains uncertain (Ziegler *et al.* 2016; Novaes *et al.* 2018; Teta 2019). Recent authorities suggest the South American population of Hoary Bats (*L.c. villosissimus*) and one of the former subspecies found in Hawaii (*L.c. semotus*) are separate species (Baird *et al.* 2015, 2017; Moratelli *et al.* 2019; Simmons and Cirranello 2020). Because of the expected taxonomic revision, only the North American population (*L.c. cinereus*) is considered.

A taxonomic split within Eastern Red Bats has resulted in the recognition of several separate species, which were formally recognized as subspecies within Eastern Red Bats (Morales and Bickham 1995; Wilson and Reeder 2005; Baird *et al.* 2015). Most notably, this includes the Western Red Bat (*Lasiurus blossevillii*; formally *L.b. blossevillii*), which occurs across much of western North America and was once thought to occur in British Columbia. Recent genetic evidence suggests that only the Eastern Red Bat (containing only *L.b. borealis*) occurs in Canada, and has a range that extends from British Columbia to the east coast (Nagorsen and Paterson 2012; Solick *et al.* 2020).

Morphological Description

All three species have complex and varied colouration. Additionally, *Lasiurus* spp. have distinct morphology that makes them relatively easy to identify compared to genera with more cryptic species, such as *Myotis* spp.

Hoary Bat

Hoary Bats have dense fur with a complex mixture of colours, including light to dark brown with white tipped hairs which are common on both the dorsal and ventral sides (van Zyll de Jong 1985). The light yellow-brown fur on the head, throat, and the anterior margins of the wings is distinctive. Like other species of *Lasiurus*, Hoary Bats have a well furred tail. This is the largest bat species in Canada. The mass of adults averages 28 g (range = 16–38 g), forearm length ranges from 50 to 57 mm, and wingspan ranges from 34 to 41 cm (van Zyll de Jong 1985; Lausen *et al.* 2022). Females are slightly larger than males (Williams and Findley 1979).

Eastern Red Bat

Eastern Red Bat fur is usually orange, but varies from yellowish-red to yellowish-grey (van Zyll de Jong 1985). White hairs or white-tipped hairs give a frosted appearance. The skin is light-coloured on the face and along the margins of the arms and fingers but contrasts strongly with the predominantly black wing membranes. Males are typically redder than females, but this may be confounded by the tendency for smaller bats of either sex to have redder fur (Davis and Castleberry 2010). The mass of adults averages 13 g (range = 10–17 g), forearm length ranges from 36 to 43 mm, and wingspan ranges from 28 to 33 cm (Shump and Shump 1982*a*; van Zyll de Jong 1985; Lausen *et al.* 2022). As with Hoary Bats, females are slightly larger than males (Williams and Findley 1979).

Silver-haired Bat

Silver-haired bats have one of the darkest complexions of bats in Canada, with black skin membranes and black to dark brown fur (van Zyll de Jong 1985). The fur often has grey or silver-frosted tips, giving it the silvery appearance for which it is named, but intensity varies among individuals. Ears are short and the anterior margins of the ears are often light-coloured, contrasting with the otherwise black pigmentation. The nose is short and broad. The mass of adults averages 11–12 g (range = 9–17 g), forearm length ranges from 36 to 45 mm, and wingspan ranges from 20 to 35 cm (van Zyll de Jong 1985; Lausen *et al.* 2022). Sexes are similar in size and appearance (Williams and Findley 1979).

Population Spatial Structure and Variability

There is no evidence of population genetic structure in any of these three species (Vonhof and Russell 2015; Pylant *et al.* 2016; Sovic *et al.* 2016; Nagel 2022). The lack of structure is likely due to their vagility (i.e., seasonal movements of hundreds to thousands of kilometres; see **Migration**) and promiscuity. Genetic structure may result from females returning each year to the same maternity sites, but philopatry is not well understood for any of the species.

Designatable Units

There is no evidence to suggest that these bats contain designatable units (DUs) below the species level, so each species is considered to have a single DU in Canada.

Special Significance

Collectively, these bats are an important component of Canada's mammalian diversity. Hoary Bats and Eastern Red Bats are both part of a genus with several closely related species that collectively span most of North and South America. However, Hoary Bats and Eastern Red Bats are the only species of *Lasiurus* known to regularly occur in Canada. In contrast, the Silver-haired Bat is the only member of the genus *Lasionycteris*, and Canada represents a substantial portion (about 34%) of the global range for this species. The loss of these three species from Canada would have an especially high impact on the diversity of bats in Canada because it would compound the severe declines due to white-nose syndrome, which already threatens many of the other species found in Canada (COSEWIC 2013; Hoyt *et al.* 2021).

Bats are the primary predators of nocturnal aerial insects. They may limit populations of nocturnal insects, helping to reduce insect damage to forests and other habitats. Although these three bat species eat a diversity of nocturnal flying insects, moths are an especially important component of the diet for Hoary Bats and Eastern Red Bats, and possibly for Silver-haired Bats (Barclay 1985; Hickey *et al.* 1996; Clare *et al.* 2009; Reimer *et al.* 2010). Moth larvae include major plant defoliators, and several moth species are considered pests of forests and crops. Potential consequences of the loss of these bats include disruptions to ecosystems, lower crop and forest timber yields, and potentially higher use of chemical pesticides (Williams-Guillén *et al.* 2008; Boyles *et al.* 2011; Maas *et al.* 2013; Maine and Boyles 2015; Russo *et al.* 2018b).

Negative portrayals of bats represent a challenge for bat conservation (Hoffmaster *et al.* 2016; López-Baucells *et al.* 2018; MacFarlane and Rocha 2020). Much of the negative ."sentiment is because bats, along with carnivores, are believed to be the primary reservoir for rabies in North America (Constantine 1979; Fenton *et al.* 2020). More recently, assumptions regarding the role of bats in the origin of COVID-19, and unfounded fear of contracting COVID-19 from bats, may have escalated public dislike of bats (MacFarlane and Ricardo 2020). It is unlikely that populations of any of these species would be directly threatened by persecution by people because these three species rarely occupy human structures. However, negative or indifferent sentiments towards bats could result in weaker responses to conservation threats (Knight 2008; Kingston 2016).

DISTRIBUTION

Global Range

Hoary Bat

Hoary Bat is among the widest ranging native terrestrial mammals in the Western Hemisphere (Figure 1). It occurs from the boreal forest to Central America and likely spans all Canadian provinces and territories (but few records occur in Nunavut or Newfoundland and Labrador) and all USA states (Shump and Shump 1982a; Blejwas *et al.* 2014; Slough *et al.* 2014; Wilson *et al.* 2014; GBIF 2020). Hoary Bats originating from North America are the only extant terrestrial mammal to have colonized the Hawaiian Islands independent of human activities (Russell *et al.* 2015). Hoary Bats are present in Mexico year-round (Cryan 2003), and in Central America the species has been reported as far south as Honduras, although it is not known which subspecies this represents (Mora and López 2014). In South America, Hoary Bat ranges as far south as Argentina (Gardner and Handley 2007). However, the South American population has genetically diverged from the North American one (Baird *et al.* 2015).

Like Eastern Red Bats and most Silver-haired Bats, Hoary Bats move long distances across the continent during migration and thus their geographic distribution changes seasonally. Hoary Bats do not appear to regularly overwinter in Canada and are rare or absent from the country for more than half the year (Cryan 2003). During winter, they are concentrated in coastal areas of the United States and Mexico. They then migrate to northern and interior parts of the continent in the spring (Cryan 2003; Cryan *et al.* 2014a).

Eastern Red Bat

Eastern Red Bats occur primarily east of the Western Cordillera (Rocky Mountains and Sierra Madres) in Canada, the United States, and northeast Mexico (Shump and Shump 1982b; Ceballos 2014; GBIF 2020; Solick *et al*. 2020; Lausen *et al*. 2022; Figure 2). They are widespread within this region, occurring from the boreal forest to the Gulf of Mexico (Cryan 2003). The western and southern limits of their range in the United States and Mexico is poorly delineated because of confusion with Western Red Bat, which makes the validity of existing records suspect. At least some Eastern Red Bats cross the Rocky Mountains into British Columbia (Nagorsen and Paterson 2012), but occurrences are sporadic and few specimens have been recovered from the province. As with many bats in Canada, the northern extent of their range is uncertain because of low survey effort (Jung *et al*. 2014).

Eastern Red Bats are long-distance migrants, with some individuals moving hundreds or thousands of kilometers between summer and winter months. They appear to overwinter primarily in the southeastern United States and then disperse towards the interior and northern regions of the continent during summer (Cryan 2003).

Silver-haired Bat

Silver-haired Bat is widely distributed throughout North America (Figure 3), occurring from the southern Northwest Territories (Wilson *et al*. 2014) to the state of Tamaulipas, Mexico (Ceballos 2014). It occurs across most of Canada, from British Columbia to New Brunswick and Nova Scotia, but appears to be uncommon in Atlantic Canada (McAlpine *et al*. 2021). The species occurs throughout the continental United States. The northern and southern limits of its distribution are poorly delineated.

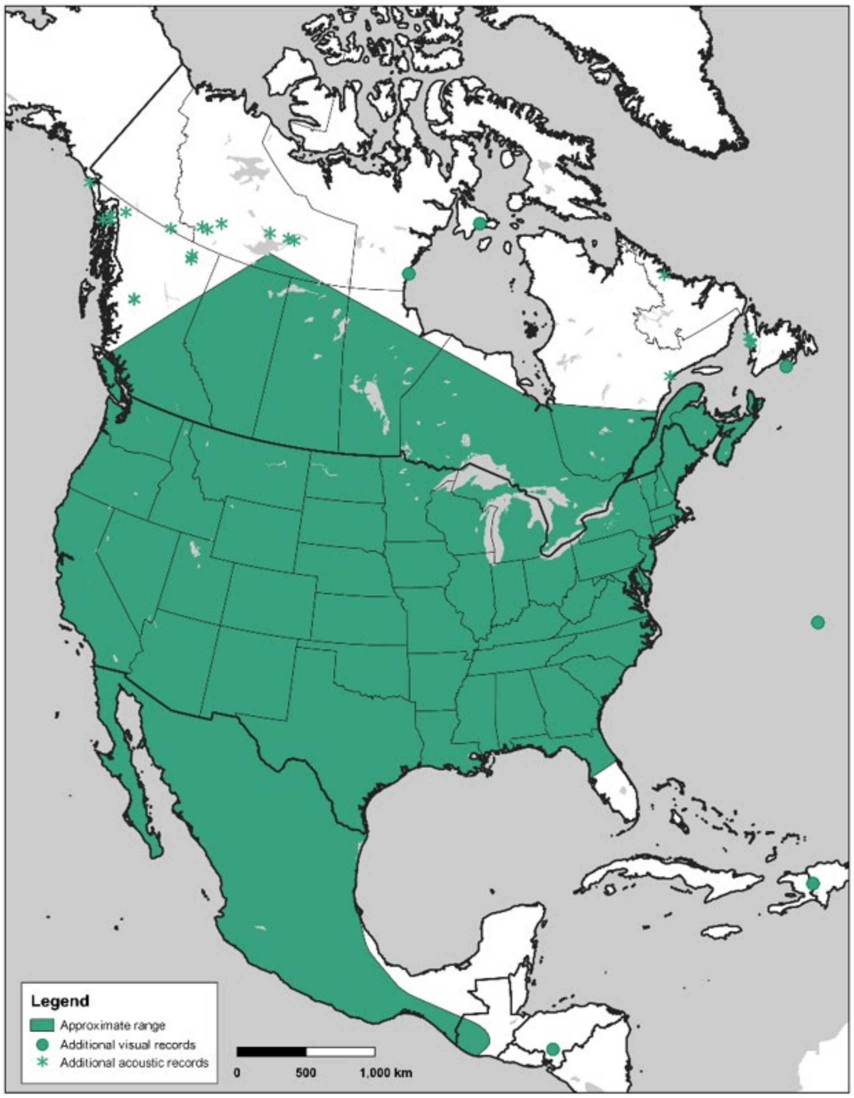

Figure 1. Approximate distribution of Hoary Bat based on visual records in green, additional visual records represented with green dots, and additional acoustic records represented with an asterisk. Data are insufficient to accurately delineate the northern range limits of this species. Winter range based on Cryan and Veilleux (2007) but not differentiated in this figure. Sources: Hitchcock 1943; Shump and Shump 1982a; Anand-Wheeler 2002; Maisonneuve *et al*. 2008; Stantec Consulting Ltd 2012; Blejwas *et al*. 2014; Mora and López 2014; Slough *et al.* 2014; Wilson *et al.* 2014; Hansen *et al.* 2018; de Lacoste and SFEPM 2020; Faure-Lacroix *et al.* 2020; GBIF.org 2020; Washinger *et al.* 2020; Rae and Lausen 2021; Slough *et al.* 2022' Humber pers. comm. 2023; New Brunswick Museum (NBM-5801, NBM-1202).

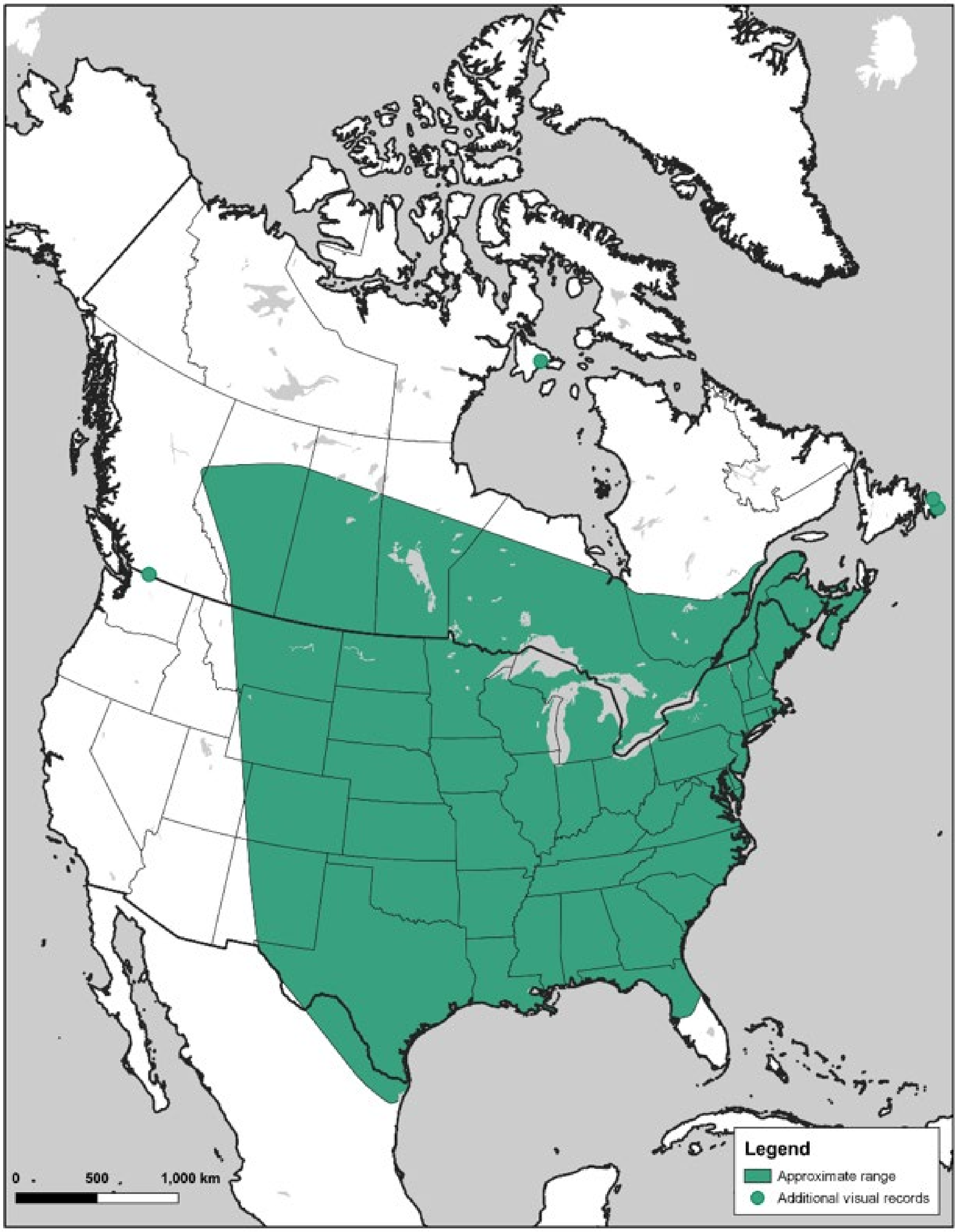

Figure 2. Approximate distribution of Eastern Red Bat based on visual records in green and additional visual records represented with green dots. Data are insufficient to accurately delineate the northern range limits of this species. Sources: Nagorsen and Nash 1984; Knowles 2005; Brown and Hamilton 2006; Lucas and Hebda 2011; Nagorsen and Paterson 2012; Natural Resource Solutions Inc. 2012; Cebellos 2014; AEP 2018; GBIF.org 2020; Solick *et al.* 2020; Humber pers. comm. 2023; Canadian Museum of Nature (CMNMA 2822); R, Barclay unpub. data; Klymko pers. comm.

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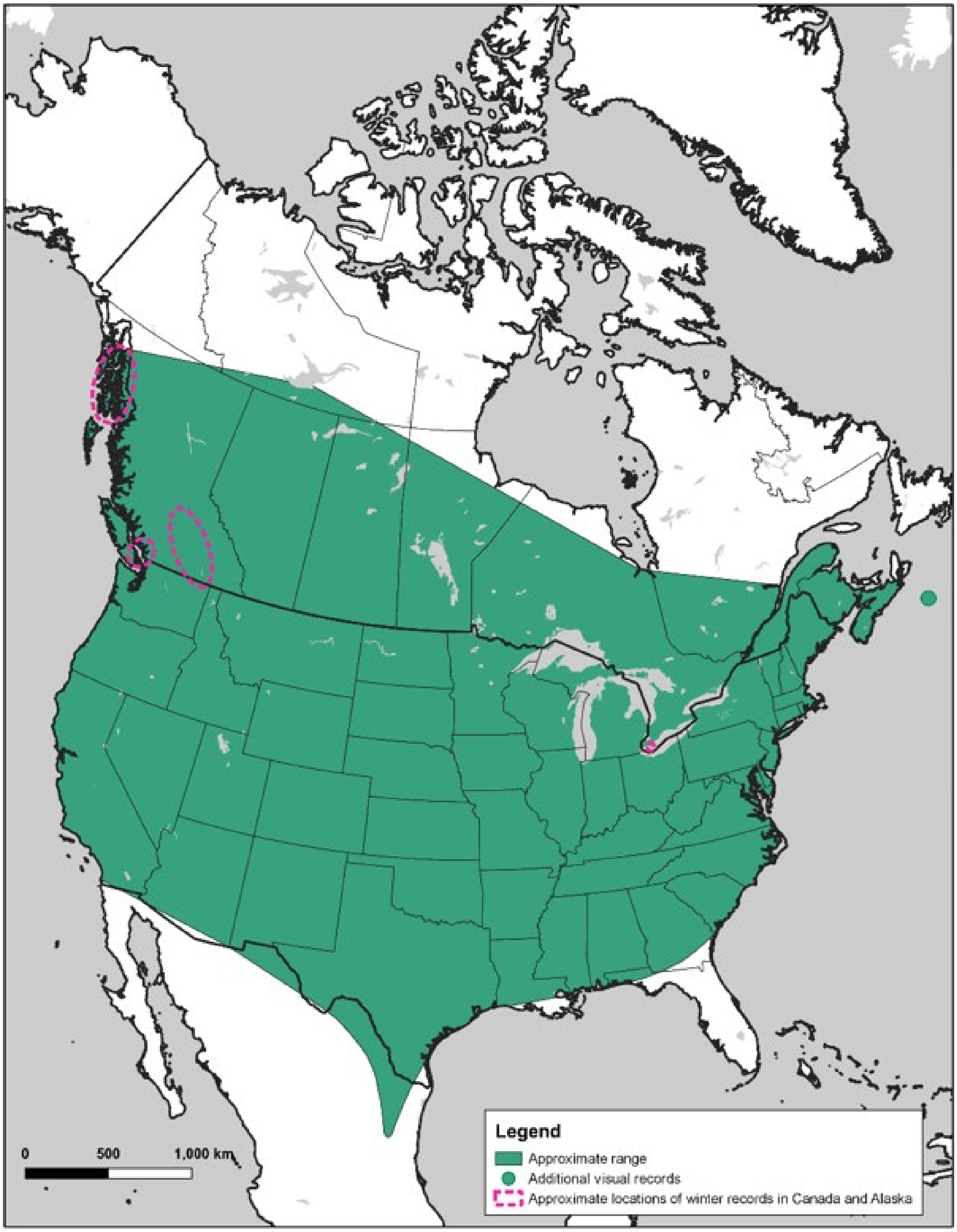

Figure 3. Approximate distribution of Silver-haired Bat based on visual records in green and additional visual records represented with green dots. Approximate area with winter records of Silver-haired Bats are outlined with pink dashes. Data are insufficient to accurately delineate the northern range limits of this species. Sources: Nagorsen and Nash 1984; Parker *et al.* 1997; *Lucas* and Hebda 2011; Stantec Consulting Ltd 2012; Blejwas *et al.* 2014; Wilson *et al.* 2014; GBIF.org 2020; Lausen *et al.* in press; BC Community Bat Program unpub. data.

Silver-haired Bats are long-distance migrants and their distribution changes seasonally. They are uncommon in the southeastern United States during the summer and absent from most of Canada during winter (Cryan 2003). They overwinter across much of the contiguous United States and Mexico, coastal regions of British Columbia and southeast Alaska, southern British Columbia, and around the Great Lakes region (Parker *et al*. 1997; Kurta *et al*. 2018; GBIF 2020; Lausen *et al*. 2022; Figure 3).

Canadian Range

Hoary Bat

Hoary Bat is widespread in Canada during the summer months and recorded in all provinces and territories (Figure 1). The species has been reported near Arviat and Coral Harbour (Southampton Island) in Nunavut (Hitchcock 1943; Anand-Wheeler 2002), but it is unlikely the bats occur regularly there. In the Northwest Territories, Hoary Bats have been identified acoustically near Great Slave Lake, Wood Buffalo National Park, and Nahanni National Park Reserve (Lausen *et al.* 2014; Wilson *et al.* 2014; Hansen *et al.* 2018) and there is a visual record from near Fort Resolution (Soper 1942). The species has also been detected acoustically in southern Yukon (Slough *et al.* 2014), Quebec (Faure-Lacroix *et al.* 2020) and visual and acoustic records occur in southeastern Alaska and elsewhere in northern British Columbia (Parker *et al.* 1997; Blejwas *et al.* 2014; Lausen *et al.* 2022). In Ontario, they appear to have among the most northern distribution of the three species (Layng *et al.* 2019) and have been found near James Bay during migration (Nagorsen and Nash 1984). The species is uncommon in the Atlantic provinces, but has been recorded in Prince Edward Island (McAlpine *et al.* 2002; Henderson *et al.* 2009), New Brunswick (Atlantic CDC / New Brunswick Museum records), Nova Scotia (Broders *et al.* 2003; Segers *et al.* 2013), and the island of Newfoundland (Maunder 1988). It is the most common migratory bat found dead at wind farms in the Atlantic Provinces, although fatalities are relatively few compared to further west (Bird Studies Canada *et al.* 2018). Hoary Bats have also been reported on islands, boats, and oil platforms off the east coast (Lucas and Hebda 2011; Humber pers. comm. 2023), suggesting they migrate over open water along the coast. Despite being a tree-roosting species, Hoary Bats have been documented migrating through and breeding in large expanses of open prairie habitats, possibly taking advantage of trees associated with watercourses and human settlements (Holloway and Barclay 2000; Olson 2019).

Eastern Red Bat

Eastern Red Bat has been found in all Canadian provinces except Prince Edward Island (Figure 2) but appears to be uncommon across most of British Columbia and the Atlantic provinces, and its distribution is mostly unknown in northern Canada (Jung *et al.* 2014; Slough *et al.* 2022), including all three territories. There is an incidental report of a flying bat and possible acoustic detections that appear to be this species in Nahanni National Park Reserve, Northwest Territories (Lausen *et al.* 2014). The species was captured in Coral Harbor, Nunavut (Canadian Museum of Nature CMNMA27822), but it is unclear if this represents a regular occurrence. Eastern Red Bats have been found dead at wind farms in northeast British Columbia (Nagorsen and Paterson 2012) and there is a museum record from 1905 in the southern interior of the province, which has been genetically confirmed to be an Eastern Red Bat (Nagorsen and Paterson 2012). There are acoustic detections purported to be Eastern Red Bats across much of British Columbia (Rae and Lausen 2021; Slough *et al.* 2022). If correctly identified, these records would indicate that the species, while not common, could be widely distributed across British Columbia and in Quebec (Jutras *et al.* 2012). In Quebec, the Chirops monitoring network has acoustically monitored bats for 20 years and made numerous detections of Eastern Red Bat (Jutras *et al.* 2012; MFFP 2022). Recent acoustic studies on Prince Edward Island have recorded echolocation calls resembling those of Eastern Red Bat, suggesting the species may pass through the province during migration (Segers pers. comm. 2020). The known range of Eastern Red Bats has expanded substantially over the last few decades, but whether this is the result of a real range expansion or improved survey coverage is not known (Solick *et al.* 2020).

The species regularly occurs in Alberta, but breeding has not been documented there (Lausen and Player 2014). Reproductively active females have been captured in Saskatchewan (Willis and Brigham 2003). Both males and females were commonly captured during fall migration in Delta Marsh, Manitoba, but captures of males were more than twice as frequent as females (Barclay 1984). The species appears to be common in Ontario and Quebec based on fatality data from wind energy facilities (Bird Studies Canada *et al.* 2018; Davy *et al*. 2020). Individuals have been observed during the fall along the shore of James Bay (Nagorsen and Nash 1984) but summer detections are uncommon in the Hudson Bay region of Ontario (Layng *et al.* 2019). The species has recently been confirmed in Newfoundland (Knowles 2005; Humber pers. comm. 2023) and there are acoustic detections from Labrador (Humber pers. comm. 2023) but it has not been confirmed in Prince Edward Island (Curley *et al.* 2019) and it is uncommon in Nova Scotia. However, at least one has been confirmed breeding in Nova Scotia, where it may be more widespread (Broders *et al.* 2003; Lucas and Hebda 2011), and the species is known to occur in New Brunswick (Klymko pers. comm. 2020; McAlpine pers. comm. 2020).

<u>Silver-haired Bat</u>

Silver-haired Bat is regularly encountered across most provinces, with a range extending from Nova Scotia (Lucas and Hebda 2011) to Haida Gwaii, British Columbia (Nagorsen and Brigham 1993; Figure 3). Its distribution extends to the southern Northwest Territories (Wilson *et al.* 2014) and Yukon (Slough and Jung 2008; Slough *et al.* 2022). However, the similarity of' the echolocation calls of Silver-haired Bats and Big Brown Bats (*Eptesicus fuscus*) makes confirming their presence by acoustic detection difficult (Betts 1998a; Faure-Lacoix *et al.* 2020). The Silver-haired Bat was recently confirmed in Newfoundland and is suspected in Labrador based on acoustic observations (Humber pers. comm. 2023). It has not been reported in Nunavut or Prince Edward Island (Curley *et al.* 2019). It is uncommon in Nova Scotia (Broders *et al.* 2003) but breeding has been documented in New Brunswick (McAlpine *et al.* 2021). Sightings offshore during the fall and records in Haida Gwaii, BC and Sable Island, NS suggest that these bats fly over open water and likely migrate along coastlines, similar to the other two species (Lucas and Hebda 2011; GBIF.org 2020). In Ontario, they have been found as far north as James Bay during migration (Nagorsen and Nash 1984) but they are uncommon in the Hudson Bay region during the summer (Layng *et al.* 2019).

Within Canada, there are winter records from southern British Columbia, where individuals may be year-round residents (Nagorsen *et al.* 1993; Lausen *et al.* 2022). Overwintering Silver-haired Bats have also been reported as far north as southeast Alaska (Parker *et al.* 1997), making it likely that they overwinter throughout the west coast of British Columbia. Some individuals overwinter in the Great Lakes region, at least as far north as Point Pelee National Park (Fraser *et al.* 2017; Kurta *et al.* 2018; GBIF 2021). Winter records have also been reported in Nova Scotia (Lucas and Hebda 2011).

Extent of Occurrence and Area of Occupancy

The estimated range of these species is shown in Figures 1 to 3. Only visual records were used because of inherent issues with the reliability of acoustic identification (see **Search Effort**). The estimated extent of occurrence (EOO) for all three species is thought to be much greater than the 20,000 km^2 threshold for the application of criteria. The index area of occupancy (IAO) is similarly well above thresholds.

In developing the range maps for the three species, capture records were relied on, as identification of the three species on the basis of size, colour, and morphology is straightforward (e.g., van Zyll de Jong 1985; Lausen *et al.* 2022). Occurrence records based solely on acoustic data were not included. While recordings of bat echolocation calls can be used to assess such things as variation in overall bat activity, and some species can be identified by their calls, there is considerable intraspecific variation in call characteristics, and there is overlap among species. Call variation within a species occurs geographically (e.g., Thomas *et al.* 1987; Barclay *et al.* 1999; Russo *et al.* 2018a), among habitats (e.g., Broders *et al.* 2004; Russo *et al.* 2018a; Findlay and Barclay 2020), and with environmental conditions (e.g., Chaverri and Quirós 2017; Jacobs *et al.* 2017). Variation in recorded call characteristics and thus species identification also occurs among different recording devices, acoustic filters, and auto-ID programs (e.g., Clement *et al.* 2014; Lemen *et al.* 2015). Finally, auto-ID programs have been found to have frequent identification errors when checked by experts (e.g., Russo and Voigt 2016; Russo *et al.* 2018a), including identifying noise as Hoary Bats and Silver-haired Bats (Austin *et al.* 2018).

The species-identification issues associated with acoustic recordings of echolocation calls have led to numerous studies lumping species together when accurate identification of calls cannot be guaranteed. This is most common for Silver-haired Bats, which are often lumped with Big Brown Bats (e.g., Betts 1998c; Cox *et al.* 2016; Austin *et al.* 2018; Neece *et al.* 2019; Faure-Lacroix *et al.* 2020). In the United States, Eastern Red Bats have been lumped with Seminole Bats (*Lasiuruis seminolis*) (Neece *et al.* 2019) and the Evening Bat (*Nycticeus humeralis*) (Cox *et al.* 2016).

Given the uncertainty in acoustic detections, only species occurrence records with visual proof of identity were used to create the range maps (Figures 1, 2, 3,). These estimated ranges far exceed the thresholds for EOO and IAO and although the ranges are likely underestimates of the true species ranges, this does not affect the determination of status.

Search Effort

Search effort is generally poor for bats in Canada and concentrated in areas with higher densities of people and roads. There is particularly poor survey coverage in the north (Jung *et al.* 2014), especially using methods capable of providing reliable confirmation of species occurrences (e.g., mist-net surveys). There is also an absence of visual records of Eastern Red Bats across most of British Columbia, although reports of acoustic detections suggest the species could be widespread in the province (Rae and Lausen 2021). All three species are challenging to capture, except in some areas during migration, so visual records of live bats are typically sporadic, although carcasses of all three species are often recovered as part of post-construction fatality monitoring at wind energy facilities.

Acoustic surveys are becoming increasingly common across much of Canada (e.g., Maisonneuve *et al.* 2006; Layng *et al.* 2019; Faure-Lacroix *et al.* 2020; Rae and Lausen 2021). While the three species may have echolocation call properties that are sufficiently different to attempt species-level identification, they all produce vocalizations that are easily confused with those of other species. Overreliance on automated classification software, false assumptions because of incomplete reference call libraries, and identifications by inexperienced operators often make records of acoustic identification unreliable for species range mapping and other analyses (Lemen *et al.* 2015; Russo and Voigt 2016; Rydell *et al.* 2017). Regardless of species, most records of acoustic detections for bats across Canada lack sufficient documentation to independently evaluate the reliability of the occurrence.

The calls of Silver-haired Bats are especially easy to confuse with those of Big Brown Bat calls, while Eastern Red Bat calls are often confused with those of Little Brown Myotis (Loeb *et al.* 2015; Rae and Lausen 2021). Hoary Bats are perhaps the easiest to identify acoustically because they have shallow slope, low frequency echolocation calls thought to be unique among Canadian bats, although some echolocation recordings for these bats can still be confused with other species. For the purposes of range mapping, priority is given to visual observations.

Bat surveys with sufficiently standardized protocols to allow trend analysis have only recently begun across most areas of North America, and coverage remains poor in most regions. In some regions of Quebec, bats have also been acoustically monitored as part of the Réseau québécois d'inventaires acoustiques de chauves-souris, hereinafter referred to as the Chirops Network, which has been operating since 2000 (Lemaître et al. 2017; Faure-Lacroix *et al.* 2019, 2020; MFFP, 2022). Analyses of these trends are underway (Simard pers. comm. 2023). Acoustic monitoring is also now occurring in some regions of Canada and the United States as part of the North American Bat Monitoring Program (Loeb *et al.*

2015) but trend data are not yet available. Carcass searches at wind energy facilities provide some of the most comprehensive standardized survey data available. However, bat monitoring at wind energy installations typically lasts only a few years and comprehensive results are often not publicly available (Smallwood 2020).

HABITAT

Habitat Requirements

In general, summer habitat for these three species of migratory bats is characterized as foraging, drinking, and roost sites, with roosts being particularly important (Humphrey 1975; Fenton 1997). In Canada, these bats use mostly treed habitats for roosting or foraging, with a particularly strong dependence on trees as roosting sites. Foraging habitats are less well known, but likely include the area above aquatic habitats (Barclay 1989), low-elevation meadows, grasslands, and fields, as well as open-canopied forest, the area above forest canopies, and forest edges. Drinking habitat is not well known and assumed to be the same as aquatic foraging habitats. Winter habitat requirements are not well known for any of these species.

As habitat generalists, all three species occupy a wide diversity of habitats across their geographic range (Fenton 1997; Gehrt and Chelsvig 2004) and can efficiently move large distances to access required resources (Ethier and Fahrig 2011). However, the configuration, abundance, and quality of resources will affect habitat suitability (Duchamp *et al.* 2007; Hayes and Loeb 2007). Habitat use varies within and between seasons, and potentially between sexes, with different habitats used depending on whether individuals are occupying their summer range, migrating, or overwintering (Cryan and Veilleux 2007).

<u>Hoary Bats and Eastern Red Bats</u>

Hoary Bats and Eastern Red Bats typically roost among the foliage of trees and occasionally shrubs (Hutchinson and Lacki 2000; Mager and Nelson 2001; Elmore *et al.* 2004; Limpert *et al.* 2007; Perry *et al.* 2007; Klug *et al.* 2012). Thus, the availability of suitable trees is important for protection from predators and as sites for raising offspring (Cryan and Veilleux 2007). Hoary Bats and Eastern Red Bats roost alone, or with their pups. Their solitary roosting behaviour and well-camouflaged fur results in roosts being highly cryptic. Roost sites that have overhead foliage for cover and open flight space below are selected (Mager and Nelson 2001). Roosting appears to occur near the edge of the crown and at sufficient heights to prevent access by mammalian predators (i.e., >5 m).

Eastern Red Bats and Hoary Bats use both deciduous and coniferous forests, of any age class (O'Keefe *et al.* 2009). In some parts of their range, Eastern Red Bats avoid conifer species when suitable deciduous species are present (Elmore *et al.* 2004; Perry *et al.* 2007). Trees used as maternity roosts by Hoary Bats and Eastern Red Bats tend to be large diameter and tall, reaching or exceeding the height of the surrounding canopy (Mager and Nelson 2001; Elmore *et al.* 2004; Kalcounis-Ruppell *et al.* 2005; Willis and Brigham

2005; Limpert *et al.* 2007; Perry and Thill 2007; Klug *et al.* 2012). Male Eastern Red Bats in particular have been observed to use saplings as roosts, which is rarely reported for reproductive females (Perry *et al.* 2007).

Roost sites with southern aspects may be selected by reproductive bats to allow passive warming by the sun, and roosts are typically located in sites sheltered from the wind (Willis and Brigham 2005; Klug *et al.* 2012). Eastern Red Bats appear to select sites with reduced exposure to temperature extremes (Hutchinson and Lacki 2000).

Hoary Bat and Eastern Red Bat individuals and family groups typically use several trees during the breeding season, but individuals show high inter-annual roosting area fidelity, suggesting they do not require a large area for roosting (Elmore *et al.* 2005; Willis and Brigham 2005; Perry and Thill 2007; Walters *et al.* 2007; Klug *et al.* 2012). Individual Eastern Red Bats of a variety of sex and age classes had average roosting areas < 1 ha from June to August in Mississippi (Elmore *et al.* 2005). This was despite frequent roost switching among available trees within these areas. In Illinois, the mean roosting area for ten individuals (again adult males and females, and juveniles) was much larger (90 ha), and roost switching on consecutive days was common (58 of 61 observations) (Mager and Nelson 2001).

There is little information regarding roost switching and roost area for Hoary Bats. In New Hampshire, one Hoary Bat family roosted in six different trees over a 10-day period, with a mean distance between consecutive roosts of 42 m and a total roost home range of 0.5 ha (Veilleux *et al*. 2009). In contrast, lactating females in Manitoba rarely switched roosts (Klug *et al.* 2012) and female Hoary Bats in Saskatchewan used the same individual White Spruce (*Picea glauca*) tree for up to several weeks at a time (Willis and Brigham 2005).

Hoary Bats forage in the open, and suitable habitats may include wetlands, grasslands and open fields with patchily distributed trees (Barclay 1985, 1989). Eastern Red Bats forage in both forested and non-forested habitats, in both open and semi-cluttered habitats, both above and below forest canopies, and in both early and later stage forests (Hutchinson and Lacki 1999; Jung *et al.* 1999; Menzel *et al.* 2005; Loeb and O'Keefe 2006). Reuse of foraging areas across multiple nights appears to be common (Hutchinson and Lacki 2000; Walters *et al.* 2007; Amelon *et al.* 2014).

Foraging by lasiurines may occur in large openings, such as clearcuts, but the relationship between the size of clearings and habitat suitability is poorly understood. Several studies report Hoary Bat and Eastern Red Bat activity to either be higher in harvested stands (clearcut or partial-cut), or not significantly different, when compared with unharvested stands (Erickson and Hecker 1996; Carter *et al.* 2003; Owen *et al.* 2004; Brooks 2009; Morris *et al.* 2010; Ethier and Fahrig 2011; Jantzen and Fenton 2013; Rodriguez-San Pedro and Simonetti 2015; Cox *et al.* 2016). However, such patterns may not apply to all forest types. Although edges are often used for foraging, excessive fragmentation or clearing may reduce habitat quality (Hutchinson and Lacki 1999; Amelon *et al.* 2014). Heavily disturbed habitats, such as dense urban developments, transportation corridors, and mines, are generally avoided (Hutchinson and Lacki 2000; Walters *et al.* 2007). Foraging may occur around lights, which attract moths (Furlonger *et al.* 1987; Hickey *et al.* 1996).

Individuals of all three species migrate from summer to winter areas and then hibernate. Relatively little is known about migration and hibernation. Both Eastern Red Bats and Hoary Bats overwinter in the southern United States but their migration routes are not known. Habitat use may change seasonally as bats move between summer breeding habitat and overwintering habitat (Cryan and Veilleux 2007). During migration, fatality patterns associated with wind energy facilities suggest that both species, and also Silver-haired Bats, will cross open grasslands, agricultural fields, and other large openings, but may still choose routes close to forested habitats, such as riparian woodlands or forests associated with foothills (Baerwald and Barclay 2009). There are records of migrating Hoary Bats using offshore islands on the west coast (Cryan and Brown 2007) and barrier islands on the east coast (True *et al.* 2021), and Eastern Red Bats flying over the ocean on the east coast (Hatch *et al*. 2013). Roost use during migration appears to be more variable than during the maternity season. Non-foliage roosts are occasionally used and include shrubs, bridges, and the sides of buildings (Shump and Shump 1982a; Hendricks *et al.* 2005; Andrusiak 2008).

Little is known about the winter ecology of Hoary Bats. Like Eastern Red Bats, their winter distribution includes warmer climates in the southern United States. One male Hoary Bat tracked using a GPS tag spent a 6-month period hibernating in a Coastal Redwood (*Sequoia sempervirens*) forest in northwest California (Weller *et al.* 2016). One individual (unknown sex or age) was also recorded hibernating for over 12 days in a small shrub in central Mexico (Marin *et al.* 2021). Hoary Bats have been found roosting (or hibernating) in Spanish Moss (*Tillandsia usneoides*) during the winter (Sherman 1956), a behaviour that has also been noted for other lasiurines (Constantine 1959), and for which their pelage colour provides camouflage.

Eastern Red Bats hibernate beneath leaf litter during cold periods (Moorman 1999; Mormann and Robbins 2007). Most Red Bats in Missouri used leaf litter roosts during winter periods when the ambient temperature was less than 10ºC (Mormann and Robbins 2007). Periods of torpor (i.e., reductions in metabolic rate and body temperature) may last several days but individuals may be active during warmer days of the winter (Whitaker *et al.* 1997).

Silver-haired Bat

Roosting by Silver-haired Bats occurs primarily under bark and in the cavities of trees, making them reliant on habitats where large, decaying trees are available. Silver-haired Bats roost in a variety of large diameter coniferous and deciduous trees (Bohn 2017). Reproductive females generally roost in small groups within tree cavities or under bark (Parsons et al. 1986; Mattson et al. 1996; Betts 1998a,b; Crampton and Barclay 1998; Vonhof and Gwilliam 2007). When taken as a whole, the data indicate that the species does select specific attributes of trees to roost in. However, these attributes are not specific to particular tree species or type (deciduous or coniferous specifically) across the species range. Roost-tree species and type differ depending on the region but tree size, height, roost aspect, and cavity temperature are important characteristics (Kalcounis-Ruppell *et al*. 2005).

Deciduous species (especially Populus spp.) often have decay characteristics that make them ideal as roost sites, particularly in older forests where these features are more likely to occur (Campbell *et al*. 1996; Crampton and Barclay 1998; Jung *et al*. 1999). Heart-rot infections at the site of limb breakages often result in large well-protected inner chambers (Parsons *et al*. 2003), and large sheets of exfoliating bark are ideal for roosting. In other parts of their range, coniferous species are used (Campbell *et al*. 1996; Mattson *et al*. 1996; Vonhof and Barclay 1996). Several studies report the frequent use of old woodpecker cavities (Parsons *et al*. 1986; Mattson et al. 1996; Vonhof and Barclay 1996).

Frequent roost switching is common, even among reproductive females with dependent young (Betts 1998b; Crampton and Barclay 1998). In northern Alberta, Silver-haired Bats used roosts for an average of 2.7 days before switching (Crampton and Barclay 1998), similar to the 2.9 days reported for Oregon (Betts 1998b). Distance between consecutive roosts varies, with means of 280 m in northern Alberta (n = 5; Crampton and Barclay 1998), and 183 m in BC (n = 3; Vonhof and Barclay 1996).

Unlike lasiurines, where use of anthropogenic structures is rare, Silver-haired Bats may occasionally roost in or on buildings, especially during migration when natural roosting sites may be scarce (Schowalter *et al*. 1978a; McGuire *et al*. 2012).

Foraging by Silver-haired Bats is difficult to assess, in part because the species has similar echolocation calls to those of Big Brown Bats (Betts 1998a). Silver-haired Bats forage in young and old forest, as well as forest openings (canopy gaps), but are concentrated along forest edges (Crampton and Barclay 1995; Jung *et al*. 1999; Hogberg *et al*. 2002; Jantzen and Fenton 2013) and intact forest (Patriquin and Barclay 2003). Use of canopy gaps in old-growth pine forests (Jung *et al*. 1999) suggest that they use a 'trapline' foraging strategy (e.g., Saleh and Chittka 2007), checking on the nightly availability of prey in specific habitat patches in these forests. As for other migratory species, riparian zones may be especially important as stopover habitat and migration corridors through otherwise inhospitable terrain (Barclay et al. 1988).

Silver-haired Bats overwinter in the United States, southeastern British Columbia (Cryan 2003; Lausen and Hill 2016; Lausen *et al*. 2022) and sometimes the Great Lakes region. In the United States, it winters in the Pacific Northwest, in some areas of the southwest, and at mid-latitudes in the east, south of Michigan and east of the Mississippi River (Cryan 2003). In southeastern British Columbia, Silver-haired Bats have been documented hibernating in mines, rock crevices, trees, and snags (Lausen and Hill 2016; Lausen *et al*. 2022). Little else is known about their winter ecology.

Habitat Trends

As all three species rely on large trees for roosting, and individuals and colonies frequently switch roosts during the summer, forest stands are essential habitat. Historical conversion of forest to agricultural or urban conditions is prevalent in parts of the Canadian range of all three species, particularly in the southern portions of Ontario, Quebec, Alberta, and British Columbia. In other areas, forest harvesting and replanting removes large and decaying trees and may reduce potential roosting habitat. However, other regions, such as in southeastern Ontario, have reverted from agriculture to forest cover in the recent past (1930s to 1990s; Lancaster *et al.* 2008), which likely increased the amount of summer habitat. The increase in forest fire frequency and intensity due to climate change is also likely reducing roosting habitat. In summary, the overall habitat trend is likely decreasing for the three species in parts of Canada, stable in others, and increasing in yet others, resulting in an unknown overall net effect.

BIOLOGY

General

Unless otherwise noted, the following information on general biology and reproduction of the three species is from Shump and Shump (1982a,b) and Kunz (1982).

All three species are obligate insectivores, consuming a wide range of insects, specifically Lepidoptera, Coleoptera, Hemiptera, Diptera, Homoptera, Orthoptera, Hymenoptera, Trichoptera, and Odonata (see also Reimer *et al.* 2010; Newbern and Whidden 2019). They capture prey in-flight, via aerial-hawking. Hoary Bats have occasionally been observed killing smaller species of bats, but whether they consume these bats is unclear (Brokaw *et al.* 2016; Wine *et al.* 2019).

Life Cycle and Reproduction

While little is known about reproduction, it can be inferred from other species in Canada that the bats are promiscuous, with mating occurring during late summer/autumn migration and during winter. Females store sperm over the winter and ovulate in spring. Gestation lasts 50–60 days in Silver-haired Bats and 80–90 days in lasiurines, with pups of all three species born in late June or early July. Litter size ranges from 1 to 2 for Hoary Bats and Silver-haired Bats, and from 1 to 4 for Eastern Red Bats, which is exceptional among bat species in Canada. Long-distance migrations to regions with milder climates may permit larger litter sizes because there is less need for offspring to mature rapidly and accumulate fat stores prior to winter (Klug and Barclay 2013). *Lasiurus* is the only genus in North America that has two pairs of nipples (all others have one pair), which is likely associated with their larger litter size (Simmons 1993). Pups of Silver-haired and Eastern Red Bats are weaned at approximately five to six weeks, and at seven weeks for Hoary Bats (Koehler and Barclay 2000). Sexual maturity generally occurs in the first year (Cryan *et al.* 2012) and breeding likely occurs throughout life.

Female Silver-haired Bats form small maternity colonies, but Hoary Bats and Eastern Red Bats remain solitary. Emergence counts for reproductive colonies of Silver-haired Bats averaged 9.1 individuals per colony (n = 10 colonies, maximum = 24 individuals) in northern Alberta (Crampton and Barclay 1998), between five and 21 individuals (n = 4) in southern British Columbia (Vonhof and Barclay 1996), and between five and 16 in Oregon (n = 8 colonies; Betts 1998 a, b).

Generation Time

While necessary for estimating generation length, demographic vital rates other than litter size (i.e., survival, longevity, age-specific fecundity, etc.) have not been well documented for any of the three species. The limited available data from the IUCN Generation Calculator (IUCN 2021) were used to estimate generation time, although the estimates derived were assumed to be the lower bound for each species. Additional information was collected to estimate the upper generation time and these values are used as conservative choices for evaluating generational threats.

Generation time can be estimated from survival rates and fecundity using the IUCN calculator. For Hoary Bats, survival has been estimated to be 0.34 over the first year of life, and 0.52 per year thereafter, with the mean number of offspring per female estimated at 1.12 in the first year and 1.50 thereafter (Frick *et al.* 2017). Using these numbers, the IUCN calculator estimates generation length to be 2.23 years. Pacifici *et al.* (2013) used inferences based on the IUCN calculator to estimate generation times for all mammals. Pacifici *et al.* (2013) estimated the generation time for Hoary Bats as 5.6 years and Friedenberg and Frick (2021) also suggest 5–6 years for Hoary Bats. In this report, six years is used as the upper generation time.

The mean litter size for Eastern Red Bats has been estimated to be 2.3 (Shump and Shump 1982b), or 3.13 (n = 31 adult females; Ammerman *et al.* 2019). Given the larger litter size compared to the other two species, and assuming a stable population prior to anthropogenic causes of decline, it was inferred that survival rates are lower for this species compared to Hoary and Silver-haired Bats, with survival rates of 0.2 over the first year and 0.4 thereafter. Using those estimates and either of the fecundity values, a generation length estimate of 2.2 to 2.3 years was derived with the IUCN calculator. Pacifici *et al.* (2013) estimated the generation time for Eastern Bats as 5.6 years using data from closely related taxa with comparable body mass. In this report, six years is used as the upper generation time.

Survival and mean fecundity estimates are not available for Silver-haired Bats, but as their litter size is similar to that of Hoary Bats (1–2 young), it was inferred that the survival and mean fecundity values are similar to those for Hoary Bats and thus that the generation length is approximately two years. Another method of estimating generation length involves using the mean age of breeding individuals in a population. The mean age of Silver-haired Bat captures (n = 46) from Alberta was 3.2 years, estimated from dental annuli (Schowalter *et al.* 1978b). Therefore, the estimate of generation length for Silver-haired Bats is assumed to be between two and three years. Pacifici *et al.* (2013) estimated the generation time for Silver-haired Bats as four years. In this report, four years is used as the upper generation time.

Although the available data applied to the IUCN calculator suggested generation times of around 2 years, the consensus of experts (Barclay and Harder 2003; Pacifici *et al*. 2013) indicates that longer generation times are more likely and in line with the general pattern of slower life histories observed in bats. This is consistent with other observations such as a record of a 12-year-old captive Hoary Bat (Wilkinson and South 2002). The upper limits were used in assessing threats and rates of change and where possible ranges are provided.

Physiology and Adaptability

All three species feed primarily on insects which are captured by aerial hawking (Barclay 1985; Furlonger *et al.* 1987). To survive when there is no food, bats in Canada use one or a combination of two strategies: migration and hibernation. All three species undertake longer-distance migrations than any other bat species in Canada, often crossing provincial and national borders to spend winter in regions with more favourable climates. All three may still hibernate once they reach their winter habitats, but migration to warmer climates prolongs the period when feeding can occur and reduces their exposure to extreme winter conditions.

Like other temperate-zone vespertilionid bats, all three species can employ daily torpor and or hibernation (Dunbar 2007; Dunbar and Tomasi 2006; Willis *et al.* 2006; Weller *et al.* 2016; Marin *et al.* 2020). All three species, especially Hoary Bat and Eastern Red Bat, are well insulated and have fur that extends onto the tail membrane, giving some protection from the cold. To some extent, these species can respond to changes in habitat, climate, food availability, and physiological requirements by adjusting the frequency, duration, and depth of torpor bouts (Dunbar and Brigham 2010; Klug and Barclay 2013; Geiser *et al.* 2018). The ability of these species to adapt to different conditions may help explain their widespread distribution across North America.

Unlike other species of bats in Canada, Eastern Red Bats and Hoary Bats do not overwinter in Canada. Their northern distribution during winter is likely constrained by winter temperature and, for Eastern Red Bats, by the availability of suitable hibernacula (under leaf litter) and the depth of the snowpack.

In the USA, Eastern Red Bats hibernate under leaf litter and could be vulnerable to prescribed burns and wildfire during this period (Moorman 1999; Mormann and Robbins 2007). Almost nothing is known about the hibernation sites of Hoary Bats, but it appears to occur in forests (Weller *et al.* 2016), where they could be exposed to wildfire and forest harvesting. Silver-haired Bats in British Columbia hibernate in tree cavities, rock crevices, caves or mines depending on climatic conditions and what is locally available (Lausen and Hill 2016; Lausen *et al.* 2022). They could, therefore, be vulnerable to forest harvesting or other disturbances during winter.

None of the three species frequently roost in anthropogenic structures. To some extent, they can cross human-disturbed landscapes to reach remaining patches of suitable resources. While this ability allows them to occupy areas with high levels of human disturbance, such as cities, it also puts them at greater risk of encountering wind turbines located within agricultural fields and other low-quality habitats.

It has been postulated that differences in the respiratory system of bats and birds make bats more susceptible than birds to barotrauma caused by pressure differences around the blades of wind turbines. Visual inspections of bat carcasses recovered from wind farms found injuries consistent with this hypothesis (Baerwald *et al.* 2008; Brownlee and Whidden 2011). However, most fatalities have been associated with collisions (Rollins *et al.* 2012).

These three species are the only bat species in Canada where most males and females reach sexual maturity during their first year (Cryan *et al.* 2012). Earlier sexual maturity and greater reproductive output may help compensate for higher mortality associated with migration (Fleming *et al.* 2003).

Dispersal and Migration

Dispersal

Adult female Hoary Bats and Silver-haired Bats return to the same maternity roosts or colonies across multiple years (Baerwald and Barclay, unpub. data). However, little else is known about dispersal for any of these three species. There are few recapture records for any of them because there are no concerted banding efforts in North America, so there are limited data on juveniles returning to natal or other areas. Moreover, it is uncommon for juveniles to be captured, except in known breeding areas, such as Delta Marsh, Manitoba (Barclay 1984, 1985, 1986) and Cypress Hills, Alberta/Saskatchewan (Willis and Brigham 2005; Willis *et al.* 2006; Bohn 2017; Green *et al.* 2020). This makes it difficult to estimate dispersal.

Space Use

All three species, but especially Hoary Bats, are fast flying and use open habitats. Trees are required for roosting, which likely concentrates activity where suitable roost trees occur, such as along riparian corridors. Relatively speaking, these bats are less adapted to flying in cluttered environments than most other bats in Canada (Barclay 1985, 1986).

The echolocation call characteristics of these three species enable detection of large-bodied flying insects over relatively long distances, accommodating their fast flight speeds, particularly for Hoary Bats (Barclay 1986). Foraging may occur over a variety of landscapes but is likely concentrated in areas where beetles and moths are abundant and accessible. These areas include above the forest canopy or along forest edges (Furlonger *et al.* 1987; Kalcounis *et al.* 1999), along rivers and lakes (Barclay 1985; Holloway and Barclay 2000), and around anthropogenic lighting (Barclay 1985; Furlonger *et al.* 1987; Hickey *et al.* 1996). In Manitoba, Hoary Bats forage up to 20 km from roosts, with the average maximum foraging distance approximately 6.3 km for lactating females (Barclay 1989). They may use the same roost tree for most of the breeding season, and show high between-year fidelity, suggesting a small roosting area within their home range (Willis and Brigham 2005; Perry and Thill 2007; Klug *et al.* 2012).

Eastern Red Bats are capable of navigating semi-cluttered environments, but also use fast, open-air flight (Shump and Shump 1982b; Menzel *et al.* 2005). Foraging may occur in both forested and non-forested habitats, in both open and semi-cluttered habitats, both above and below forest canopies, and in both young and older forests (Hutchinson and Lacki 1999; Menzel *et al.* 2005; Loeb and Keefe 2006). Lactating Eastern Red Bats in Missouri had a maximum foraging distance of 20 km from their day roosts, and a mean foraging area of 1,357 ha (Amelon *et al.* 2014). In contrast, in Mississippi, Eastern Red Bats travelled a maximum of 1.2 km from day roosts to foraging areas and had a mean foraging area of 94 ha (Elmore *et al.* 2005). Males may have larger foraging areas than females (Hutchinson and Lacki 1999; Elmore *et al.* 2005).

Like Hoary Bats, Eastern Red Bats likely have high fidelity to small roosting areas within their summer home ranges (Elmore *et al.* 2005; Walters *et al.* 2007). In Kentucky, roosts used by individual males or females typically occurred within a 40 m^2 area over summer (Hutchinson and Lacki 2000).

Silver-haired Bats forage in both young and old forest, as well as forest openings, but likely concentrate along edges (Crampton and Barclay 1995; Hogberg *et al.* 2002; Jantzen and Fenton 2013). In British Columbia, a few females from the same colony moved an average of 390 m between their capture and roost sites (Vonhof and Barclay 1996). In South Dakota, individuals moved an average of 2,060 m from the site of capture to roosts (Mattson *et al.* 1996).

Migration

All three species are long-distance migrants, with Hoary Bats covering the largest distances between seasonal ranges, moving from Canada in the summer to the southern United States and Mexico in the winter (Cryan 2003; Cryan *et al.* 2014a). Eastern Red Bats likely migrate from Canada to the southeastern United States (Cryan 2003). Silver-haired Bats are documented to use stopover sites at Long Point, Ontario (McGuire *et al.* 2012) to replenish fat stores before resuming migration (King and Farner 1963; Hedenström 2008), but no such records exist for Hoary Bats or Eastern Red Bats.

Migration by Hoary Bats has been documented through acoustic detection and capture records. Capture records for Hoary Bats indicate spring arrival in Canada during late May to early June and departure beginning in mid-August (Barclay 1984; Koehler and Barclay 2000; Green *et al.* 2020). Additionally, stable isotope analysis suggests that they consistently travel long distances across a latitudinal gradient (Baerwald *et al.* 2014; Cryan *et al.* 2014a), in addition to moving between the interior of the continent and coastal regions

(Cryan *et al.* 2014a) and flying over the open ocean to islands (Cryan and Brown 2007; True *et al*. 2021). Recent evidence from California demonstrates that male Hoary Bats undertake a round-trip migration covering over 1,000 km with interspersed bouts of hibernation (Weller *et al.* 2016). Specific overwintering sites are not well documented, but include hibernation in rock crevices in California (Reyes pers. comm. 2020) and in vegetation in Mexico (Marín *et al.* 2021).

Less is known about the migratory patterns of Eastern Red Bats, but their overall behaviours are assumed to be similar to those of Hoary Bats (Shump and Shump 1982a,b; Cryan *et al.* 2014a).

Migration by Silver-haired Bats may be more nuanced compared to the pattern for the other two species. In Manitoba, the first individuals arrive in early May and the last ones depart in mid-September (Barclay 1984). Some Silver-haired Bats captured in winter at sites across North America were not far from their summering grounds (i.e., <150 km) based on stable isotope analysis of fur. Other individuals were estimated to have moved as much as 2,500 km (Fraser *et al.* 2017). Additionally, there is evidence of Silver-haired Bats overwintering at relatively northern latitudes (Beer 1956; Gosling 1977; Izor 1979; Falxa 2007), including in British Columbia (Nagorsen *et al.* 1993; Lausen and Hill 2016), and Saskatchewan (Brigham 1995), again suggesting that they do not always travel long distances to hibernate. Leapfrog migration, where subpopulations of organisms migrate beyond others (Alerstam and Högstedt 1980), has also been reported to occur (Fraser *et al.* 2017). Winter activity of Silver-haired Bats has been observed via acoustic records in the northern United States (Falxa 2007), southeast Alaska (Blejwas *et al.* 2014), and possibly southern Ontario (GBIF 2021), as well as through radio-telemetry in British Columbia (Lausen and Hill 2016). There is little or no winter activity by the other migratory species at those latitudes (Cryan 2003).

Interspecific Interactions

Interactions among these three migratory species, as well as other species, are not well documented but may include competition and predation.

In British Columbia, Silver-haired Bats have been observed hibernating with California Myotis (*Myotis californicus*) and Townsend's Big-eared Bats (*Corynorhinus townsendii*; Lausen pers. comm. 2020), often in direct contact, which presumably provides mutual thermal benefits. Interspecific agonistic and aggressive behaviour of Hoary Bats toward other bats has been documented, including apparent cases of them killing smaller bat species (Bishop 1947; Brokaw *et al.* 2016; Wine *et al.* 2019). Despite these rare observations, the main competition among bat species is likely for food. However, eco-morphologically similar species have usually evolved to partition prey resources, reducing competition (e.g., Aguirre *et al.* 2002, 2003; Vesterinen *et al.* 2018; Salinas-Ramos *et al.* 2020). Bats may compete with insectivorous birds for food, although nocturnal activity by bats reduces this competition (Speakman 1991).

The primary predators of these three bat species are unknown, but the frequency of predation is presumed to be low. Documented predators include Blue Jay (*Cyanocitta cristata*; Elwell 1962; Hoffmeister and Downes 1964), Black-billed Magpie (*Pica hudsonia*), American Crow (*Corvus brachyrhynchos*), Loggerhead Shrike (*Lanius ludovicianus*; Sarkozi and Brooks 2003), various owl species (Thomsen 1971; Forsman *et al.* 2004), Sharp-shinned Hawk (*Accipiter striatus*; Downing and Baldwin 1961), American Kestrel (*Falco sparverius*; Church 1967), domestic cats (*Felis catus*; Ancillotto *et al.* 2013; Mcruer *et al.* 2017), and Striped Skunk (*Mephitis*; Sperry 1933).

The Silver-haired Bat variant of rabies has been disproportionately associated with human rabies cases, although bat-associated human rabies is rare across North America (Constantine 1979; Fenton *et al.* 2020). Rabies rates in free-flying populations of these species are likely low. From a sample of bats collected at wind facilities in Alberta, 0 of 121 Hoary Bats and 1 of 96 (1%) Silver-haired Bats tested positive for rabies (Klug *et al.* 2011).

POPULATION SIZES AND TRENDS

Sampling Efforts and Methods

In general, bat abundance is difficult to determine, given that these animals are small, vagile, and nocturnal. This is particularly true for these three migratory bat species because they often are rare in local bat assemblages (Crampton and Barclay 1998; Jung *et al.* 1999; Kalcounis *et al.* 1999; Broders *et al.* 2003; Coleman and Barclay 2012; Luszcz and Barclay 2016), have comparatively large home ranges, and often fly too high to be captured using conventional mist netting, except when drinking.

The primary means used to assess relative abundance of bats include mark-recapture studies (Kunz and Parsons 2009), acoustic detection (e.g., Grindal and Brigham 1999; Patriquin and Barclay 2003; Thomas and Jung 2019), and emergence counts (e.g., Warren and Witter 2002; Ritzi *et al.* 2005; Slough and Jung 2020). Other techniques, such as guano traps (Gellman and Zielinski 1996; Adam and Hayes 2000; Brigham *et al.* 2002) or thermal imaging (Betke *et al.* 2008; Azmy *et al.* 2012), have seen more limited use. Live captures are often superior to other methods for monitoring bats because movements, site fidelity, reproductive condition, demographic parameters, and more can be obtained through mark-recapture studies. Unfortunately, capturing bats is time and labour intensive and some species (such as these three) are not particularly susceptible to capture. Active and, especially, passive monitoring of echolocation calls with ultrasonic detectors circumvents many of the limitations and sampling biases associated with mark-recapture studies. However, identifying bat species by their echolocation calls is challenging and imprecise (Barclay 1999; Russo *et al.* 2018a). High quality recordings of diagnostic sequences of the echolocation calls of Eastern Red Bats and Hoary Bats can often be identified to species with reasonable confidence. However, recordings can be confused with other species, especially for Silver-haired Bats, which are often confused with Big Brown Bats (Betts 1998a). Moreover, acoustic monitoring initiatives based on fixed-location detectors provide only an index of activity or data needed to model occupancy based on presence-absence (Loeb *et al.* 2015). In some situations, high activity may be the result of the same bat making repeated passes past a microphone. Properly designed mobile acoustic transects may provide a measure of relative abundance but are typically constrained to roads and are more labour intensive. Emergence counts are not applicable to Hoary Bats or Eastern Red Bats because adults roost alone or with their dependent young.

There are few long-term coordinated large-scale monitoring protocols or programs for Canadian bats, unlike the situation in the United Kingdom (Barlow *et al.* 2015) or for birds (i.e., Breeding Bird Survey, Christmas Bird Count, etc.). Long-term acoustic monitoring at a continental scale has only recently begun in North America, in the form of the North American Bat Monitoring Program (NABat) (Loeb *et al.* 2015; Reichert *et al.* 2021). NABat aims to provide long-term population trend data at the continental scale, but not enough data are available to permit analysis of trends. In Quebec, bats have also been acoustically monitored as part of the Chirops Network since 2000 (Jutras *et al*. 2012). This network has been refined and expanded over time to include transects in 16 regions of the province, and analyses of longer-term trends are starting to be available (Faure-Lacroix *et al.* 2019, 2020; MFFP 2022).

Given these limitations related to available data, other sources of information were used to assess population trends, including carcass searches at wind energy facilities, rabies submission rates, and population viability modelling that relied on expert elicitation (Frick *et al.* 2017). Both observational data (i.e., historical observations of aggregations, short-term changes in capture and detection rates, rabies testing submission rates, and numbers of carcasses at wind energy facilities) and inferred data (changes to aerial insectivorous, migratory birds) were examined. Carcass searches at wind energy facilities (e.g., Davy *et al.* 2020) likely provide the most comprehensive standardized survey data available for these three species.

Abundance, Fluctuations, and Trends

Current population levels for all three species are unknown; however, expert elicitation postulated that the most likely population size of Hoary Bats across North America is approximately 2.25 million individuals (Frick *et al.* 2017). Given the similarities in life history, ecology, and distribution, it is assumed that this estimate can also be broadly applied to Silver-haired Bats and Eastern Red Bats. As relatively long-lived species with low fecundity, populations of these three bat species are not believed to naturally fluctuate.

Recently, multiple genetic studies have independently derived estimates of effective population size of all three species across North America. For example, analysis of 18–19 microsatellites from Hoary Bats and Silver-haired Bats from several sites across Canada found surprisingly low values for contemporary effective population size (N_e): 1,062 for Hoary Bats (95% CI: 652.2 to 2,661.4) and 600.4 for Silver-Haired Bats (95% CI: 315.4to 3,570.3; Nagel 2022). Pylant *et al.* (2016) used 14 microsatellites of Eastern Red Bats and Hoary Bats found at wind-energy facilities in Maryland, West Virginia, and Pennsylvania and, using coalescent modelling, they reported an N_e of ~335,000 for Eastern Red Bats (95% CI: 0.06 to 2.61 million), but a much smaller N_e for Hoary Bats (~1,600, 95% CI: 662 to 4,697). Newer work using single-nucleotide polymorphisms (SNPs) from bats collected at dozens of locations across North America and coalescent modelling suggests that Eastern Red Bats have a contemporary N_e in the range of 126,142 to 131,153, Hoary Bats have a N_e in the range of 101,355 to 106,128, and Silver-haired Bats have a N_e in the range of 49,551 to 64,801 (Nagel 2022; Nagel *et al.* submitted)

The ratio of effective population size to adult census size is unknown, but reviews suggest it is close to 0.10–0.23 across many species of wildlife (Frankham 1995; Palstra and Fraser 2012). If true for Hoary Bats, Eastern Red Bats, and Silver-Haired Bats, this suggests that the population size is unlikely to exceed the estimate of 2.5 million that is used as the "most likely estimate" in modelling publications (Frick *et al.* 2017; Friedenberg and Frick 2021). There is much uncertainty around how genetic estimates of effective population size relate to census size. N_e is presented here to provide caution that models using 2.5 million bats as most likely may underestimate declines and extinction risk.

<u>Population Modelling Projections</u>

A population viability analysis based on population parameters suspected to be relevant and important and documented fatality rates has shown that, even under optimistic scenarios, Hoary Bats are likely to experience precipitous population declines across North America and an increased risk of extinction over 50 to 100 years (Frick *et al.* 2017; Friedenberg and Frick 2021). Frick *et al.* (2017) used expert elicitation and projected fatality rates to model the effect of wind energy production on Hoary Bat populations in North America. Species experts estimated basic population parameters, including population size, survivorship, and fecundity, and then modelled population changes based on uncertainty in the reported estimates. Using the "most likely" demographic scenario, they predicted that fatalities associated with wind energy facilities would result in as much as a 90% population decline over 50 years (holding fatality rates constant at 2014 levels) with a 22% probability of extinction over the next 100 years. A 90% decline over 50 years is equivalent to an average annual decline of 4.5% and a decline of 36.9% over 10 years. Under their more "optimistic scenario," a population decline of 50% over 50 years was predicted, which is equivalent to a 1.4% annual decline (13.0% over 10 years). The optimistic scenario was based on the highest reasonable estimate for population size (2.5 million) derived by the panel of experts, and a population growth rate consistent with that for other bat species ($\lambda = 1.01$). However, this estimate is at the very upper end of what experts considered reasonable (rick *et al.* 2017) and may be less likely if population sizes are lower, as may be suggested by calculations of effective population size which indicate that there are tens of thousands of mature Hoary Bats in North America rather than millions.

Both the "most likely" and the "optimistic" scenarios of Frick *et al.* (2017) were based on models that assume an intrinsic growth rate (λ) of 1.01 prior to the effect of wind energy production. This assumption means that the population was increasing prior to the impacts of wind energy, otherwise the results underestimate the projected population decline resulting from wind energy. Likewise, projected declines and the risk of extinction would be much higher if the true population size were substantially below the "most likely" population estimate. For example, if the true population size was 1 million individuals (the lowest reasonable estimate of population size), then the population could only sustain mortality from wind turbines if the population growth rate (λ) was well above 1.10 (i.e., 10% annual growth rate), which is above most published estimates of growth rates for other bat species (Frick *et al.* 2017).

An important limitation of the Frick *et al.* (2017) analysis is the assumption that wind energy production would remain constant at 2014 levels. However, in the United States this production level had increased by 46% by the end of 2018, and by 118% by the end of 2022 (WindExchange 2023), meaning the Frick *et al.*(2017) model potentially underestimated the present rate of decline.

A more recent follow-up study by Friedenberg and Frick (2021) modelled scenarios between 2012 and 2050 and accounted for projected build-out and various mitigation scenarios to reduce fatality rates. Their models also predict large declines in Hoary Bats and state that "current levels of wind energy build-out may have already caused substantial population declines… [a]t low initial abundance, mortality rates were sufficiently high to drive a 50% reduction in the Hoary Bat population before 2019 regardless of the strength of the density-dependent demographic response or build-out scenario" and "[u]nder our lowest-risk scenario of high maximum growth rate and low wind energy build-out, the median simulated population of 2.25 million Hoary Bats will experience a 50% decline by 2028" (see their Figure 1). In various build-out models, extinction risk by 2050 (30 years, 5 generations) ranged from 0% to 40% with a midpoint of 20%.

Observed Population Declines

There are three lines of evidence to suggest that actual population declines have been occurring in migratory tree-roosting bats. First, there are numerous historical counts of large flocks (>100 individuals) of migrating Eastern Red Bats and Hoary Bats, many of which are accounts of large flocks of bats migrating during the day (Mearns 1898; Howell 1908; Allen 1939; Hall 1946). There are no recent accounts of either large flocks of bats or diurnal migration (Winhold *et al.* 2008). Secondly, capture rates of lasiurine bats have declined across North America (Whitaker *et al.* 2002; Carter *et al.* 2003). For example, in a Michigan-based study, between 1978–1979 and 2004–2006, captures of Eastern Red Bats declined by 52–85% (Winhold *et al.* 2008). The previous two lines of evidence predate the rapid expansion of wind energy generation, suggesting that longer term declines are acting cumulatively with current threats. Thirdly, although biased towards downed bats or individuals acting abnormally, the number of bats submitted for rabies testing can be used as a relative index of abundance. Across the United States, submission rates of lasiurines have decreased. For instance, in Arkansas from 1938 to 1998, the number of Eastern Red Bats submitted decreased by approximately three bats per year (Carter *et al.* 2003). There was a 10-fold decrease over 38 years in Michigan (Winhold *et al.* 2008). In Indiana, the proportion of Eastern Red Bats declined from 23% of all bats submitted between 1966 and 1969 to 16% between 1990 and 2000, and the proportion of Hoary Bats submitted declined from 3.8% to 1.8% during the same time period (Whitaker *et al.* 2002).

Recently, Barclay and Baerwald (in prep.) assessed population change based on changes in fatality rates at wind turbines for all three species, at 82 wind facilities across North America. For Hoary Bats, they found significantly more sites (54 out 82, 65.9%) had a decline in fatality rate over time than had an increase ($z = 2.76$; $p = 0.003$). Eastern Red Bat fatalities were recorded at 67 sites, 37 (55.2%) of which had a decline in fatality over time ($z = 0.73$, $p = 0.23$). For Silver-haired Bats, significantly more sites (51 of 77, 66.2%) had a decline in fatality rate over time than an increase in fatality rate ($z = 2.74$, $p = 0.003$). These results suggest ongoing declines in population size across North America.

In Ontario, Davy *et al.* (2020) reported that the number of carcasses found under wind turbines in Ontario during the late summer and autumn migration declined significantly over seven years: Hoary Bats (-21%/year), Silver-haired Bats (-29%/year), and Eastern Red Bats (-27%/year).

In Quebec, MacGregor and Lemaître (2020) analysed data from surveys at 30 wind energy facilities. They found that the majority of carcasses were of migratory bats (Hoary Bats 47%, Silver-haired Bats 18%, and Eastern Red Bats 6%); however, not all wind turbines contributed to the mortality equally, which suggests that careful planning could minimize the risk to bat populations.

Corrected fatality rates for migratory bats are available from six wind facilities in southwestern Alberta, Canada (Barclay *et al.* 2017; Barclay and Baerwald in prep.). The data cover the period from 2005 to 2011, with a total sample size of 14 facility-years. The fatality rate for Hoary Bats declined significantly over time (rate = -2.93 year + 5888, $r^2 = 0.643$, $t = -4.65$, df = 12, $p < 0.001$), as did the rate for Silver-haired Bats (rate = -1.66year + 3337, $r^2 = 0.825$, $t = -7.51$, df = 12, $p < 0.0001$). The fatality rate for Hoary Bats declined by an average of 13.4% per year. The fatality rate for Silver-haired Bats declined by an average of 12.5% per year.

The most likely, and most parsimonious, explanation for declining fatality rates of bats at wind turbines over time, is that there are fewer bats available to be killed as population sizes decline. It has been suggested that bats may be learning to avoid turbines, but there is no evidence to support this (Davy *et al.* 2020). In fact, the numerous convoluted steps that would be required for this to occur (e.g., surviving a near-fatality, associating it with a specific risky situation or behaviour, and avoiding that specific situation or behaviour in the future) at levels great enough to affect fatality rates makes this scenario highly improbable.

Multi-year acoustic and capture studies also provide data relevant to population changes for all three species. Data for Hoary Bats from eight of 12 studies revealed a decline in detection or capture rates. For Eastern Red Bats, eight of 14 studies reported a decline, while for Silver-haired Bats, four of eight indicated a decline in detection or capture rates over time, and four reported an increase (Barclay and Baerwald in prep.).

In the USA, all three species have declined in the proportion of overall bat submissions for rabies testing. Hoary Bats declined the most, from 0.81% in 1993–2000 to 0.19% between 2009 and 2018, a 76.3% decline. The change was statistically significant (Yate's $\chi2 = 360.9$, $p < 0.0001$). Eastern Red Bats declined from 1.66% of all submissions to 0.69% (a 58.1% decline; Yate's $\chi2 = 291.3$, $p < 0.0001$), and Silver Haired Bats declined from 1.80% to 0.71% (a 60.8% decline; Yate's $\chi2 = 376.4$, $p < 0.0001$).

There are multiple lines of evidence indicating that all three species of bat have declined within the last 2–3 generations (6–18 years), are currently declining, and will continue to decline over the next 2–3 generations. For Hoary Bats, using the estimate reported by Davy *et al.* (2020), specifically, a 21% annual decrease in population size year after year (2020), and assuming no replacement, it is calculated that there would be a decrease in population size of 75.7% after 6 years and 88% after 18 years. For Eastern Red Bats, using an annual decrease in population size of 27% year after year (Davy *et al.* 2020), and assuming no replacement, the decrease in population size would be 84.7% after 6 years and 94.1% after 18 years. For Silver-Haired Bats, using an annual decrease in population number of 29% year after year (Davy *et al.* 2020), and assuming no replacement, the decrease in population size would be 87.2% after 4 years and 95.4% after 12 years.

Occupancy modelling using data from the United States Pacific Northwest provides evidence of a decline in the regional probability occurrence of Hoary Bats (2016–2018 relative to 2010) of ~2%/year (Rodhouse *et al.* 2019). Considering the distances Hoary Bats are capable of flying (e.g., >1,000 km in a single month; Weller *et al.* 2016) and the proximity of Oregon and Washington to Canada, it is likely that the declines in these states include individuals that summer in Canada.

Inferred Population Declines

Populations of once abundant aerial-foraging insectivorous birds have been declining dramatically across North America and Europe (Sanderson *et al.* 2006; Blancher *et al.* 2009; Møller 2019; see also **Threats Section**). For example, since the late 1960s, Canadian populations of Chimney Swift (*Chaetura pelagica*) are estimated to have declined by more than 95%, Common Nighthawk (*Chordeiles minor*) by 80%, and Olive-sided Flycatcher (*Contopus cooperi*) by 79% (Hutchings and Festa-Bianchet 2009). More recent estimates for these species have retained declining trends of -87.9%, -68.1%, and -76.7%, respectively (Smith *et al.* 2023). The reasons for the decline in aerial insectivorous birds are numerous, but primary amongst these is the global decline in insect abundance. If populations of aerial-foraging insectivorous birds have declined so dramatically in the last 50 years, it stands to reason that migratory insectivorous bats have also suffered both historical and current declines.

At large scales, population declines for migratory bats seem clear, but at local scales there seems to be some variation (MacGregor and Lemaître 2020) and some areas may serve as important reproductive habitat, and have experienced no change in abundance (Green *et al.* 2020).

Rescue Effect

All three species of migratory bats occur in several American states bordering Canada, including Alaska for the Hoary Bat and Silver-haired Bat. Their conservation status based on NatureServe Subnational Ranks varies among the bordering states, with several indicating that populations are not secure (e.g., S3S4 or higher; Idaho, Montana, Washington, New York, New Hampshire; Table 2). Additionally, although all three species can migrate long distances and presumably occupy or (re-)colonize suitable habitat, the degree of seasonal range fidelity is not well known. Moreover, many of the threats to all three species may be even greater in the lower 48 states than they are in Canada (e.g., wind turbines, habitat loss, pollutants). While possible, the potential for rescue of Canadian populations by those in the United States is unknown and likely low, even though they may be panmictic.

THREATS AND LIMITING FACTORS

Threats

The threats to these three migratory bats were assessed and organized according to the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (Master *et al.* 2012) using the standardized lexicon of threats developed by Salafsky *et al.* (2008). Threats are defined as the proximate activities or processes that directly and negatively affect the population. This assessment addresses threats to the three species of migratory bats while in Canada, as well as during migration and on their wintering grounds outside of Canada. Threats are based on the perspectives provided by the species experts who assigned the overall threat impact of Very High-High for all three species (Appendices 1 to 3).

In the following, Threats are organized from the highest to the lowest, and bundled where appropriate. Cumulative impacts for bundled threats are provided.

<u>Wind Energy Development – High to Very High Impact</u>

Threat 3.3: Renewable Energy

Description of threat:

Wind energy development represents the greatest threat to all three species. Migration is a high-risk activity and, as long-distance migrants, Hoary, Silver-haired, and Eastern Red Bats are vulnerable to numerous and diverse threats across the continent (Fleming *et al.* 2003). Migratory bats are the most common group of bats killed by wind turbines in North America, and these three species compose approximately 75% to 80% of bat fatalities (Arnett and Baerwald 2013). Wind energy developments are currently widespread in southern Canada and in the United States, particularly in the Central and Mississippi flyways used by birds (Figure 4).

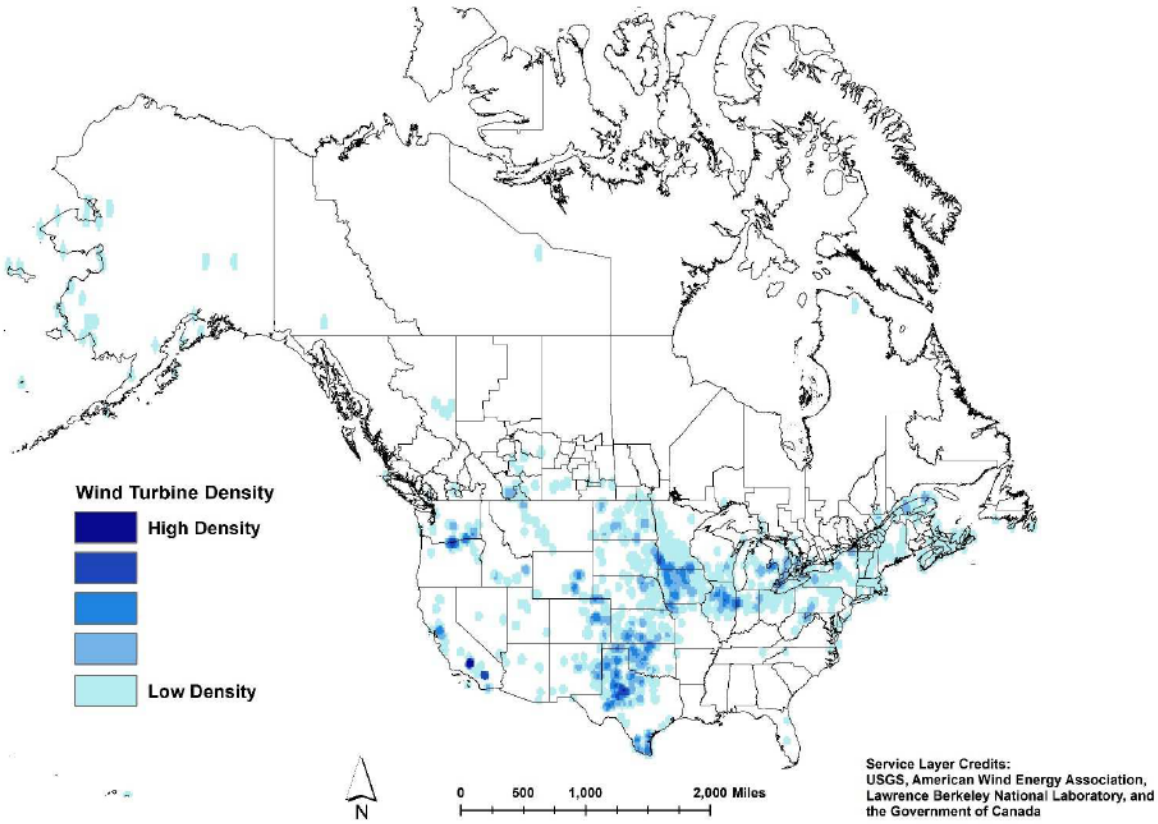

Figure 4. Distribution and density of wind energy facilities across the United States and Canada circa 2020 (Figure 1 in Bessette and Crawford 2022).

Most bats are killed by being struck by rotating turbine blades, although a small fraction of them appears to be killed by barotrauma associated with acute differences in air pressure near the turbine blades (Baerwald *et al.* 2008; Grodsky *et al.* 2011; Rollins *et al.* 2012; Allison *et al.* 2019; Lawson *et al.* 2020). Bats seem to be attracted to turbines (Cryan *et al.* 2014b; Richardson *et al.* 2021), thus exacerbating the issue, but the reasons for this attraction are unclear.

It is difficult to determine the absolute significance of fatalities because the total population size of the three species is unknown. Also, accurate estimates of fatality rates are difficult to obtain because carcasses can be hard to locate due to vegetation, decomposition, scavengers, searcher ability, and the size of area searched (Huso 2011; Korner-Nievergelt *et al.* 2011). Regulatory agencies generally require the use of a fatality estimator that applies various correction factors to the number of carcasses found at each turbine (e.g., OMNR 2011). Once corrected for the various biases, estimated fatality rates are often an order of magnitude greater than the number of carcasses found. For example, at one 86-turbine wind farm in southeastern Ontario (Wolfe Island), an estimated 1,920 bats were killed in one year, based on 118 carcasses found (Stantec Consulting Ltd. 2010, 2011). In Quebec, it was estimated that mortalities of Hoary Bats in 2016 alone fell within upper and lower 95% credible intervals of 2,128 and 3,035, respectively, based on 126 carcasses found (MacGregor and Lemaître 2020). However, those estimates were also based on correction factors applied to the relatively few total carcasses found, and the assumption that Hoary Bats represented 46% of all bat mortalities at wind energy facilities in Quebec that year. Recent analysis of acoustic records suggests that migratory bat populations may be more stable in Quebec (Simard pers. comm. 2023).

Migration routes, distance travelled, and the proportion of a population that migrates are essential factors to consider when assessing the threat of wind turbines to these three species of bats, but little is known of their movements within Canada. Fatalities at wind energy facilities indicate that migration begins in Canada by the middle of July, peaks in early to mid-August, and then subsides by mid-September, but this appears to vary with latitude and species (Baerwald and Barclay 2011; Davy *et al.* 2020). Adult male Hoary Bats appear to move through southern Canada earlier in fall than females and juveniles, but timing appears similar across age and sex classes in Silver-haired Bats (Baerwald and Barclay 2011).

Over the last decade, installed wind energy capacity has grown dramatically worldwide, from approximately 177.8 Gigawatts (GW) in 2010 to approximately 650.8 GW at the end of 2019 (IRENA 2021; WWEA 2021). As of December 2019, 7% of electricity in the USA and 6% of electricity in Canada was generated by wind energy, with targets to increase to 20% by 2025 in Canada and by 2030 in the USA (USDOE 2015; NEB 2017; Figure 5). As such, it is one of the fastest-growing sources of electricity generation in North America, with installed capacity growing at a rate of about 23% a year. Furthermore, offshore developments on the Atlantic coast are also being considered. These pose the additional issue of mortality searches being problematic or impossible if carcasses are lost to the sea. The Canadian Wind Energy Association estimates Canada had 13.4 GW (approximately 6,700 turbines at over 300 wind energy sites) installed at the end of 2019 (CANWEA 2021). The US Department of Energy forecasts that 241 GW will be needed to meet their goal of 20% energy from wind by 2030. As of January 2020, the total installed capacity was 105.6 GW (WINDExchange 2021).

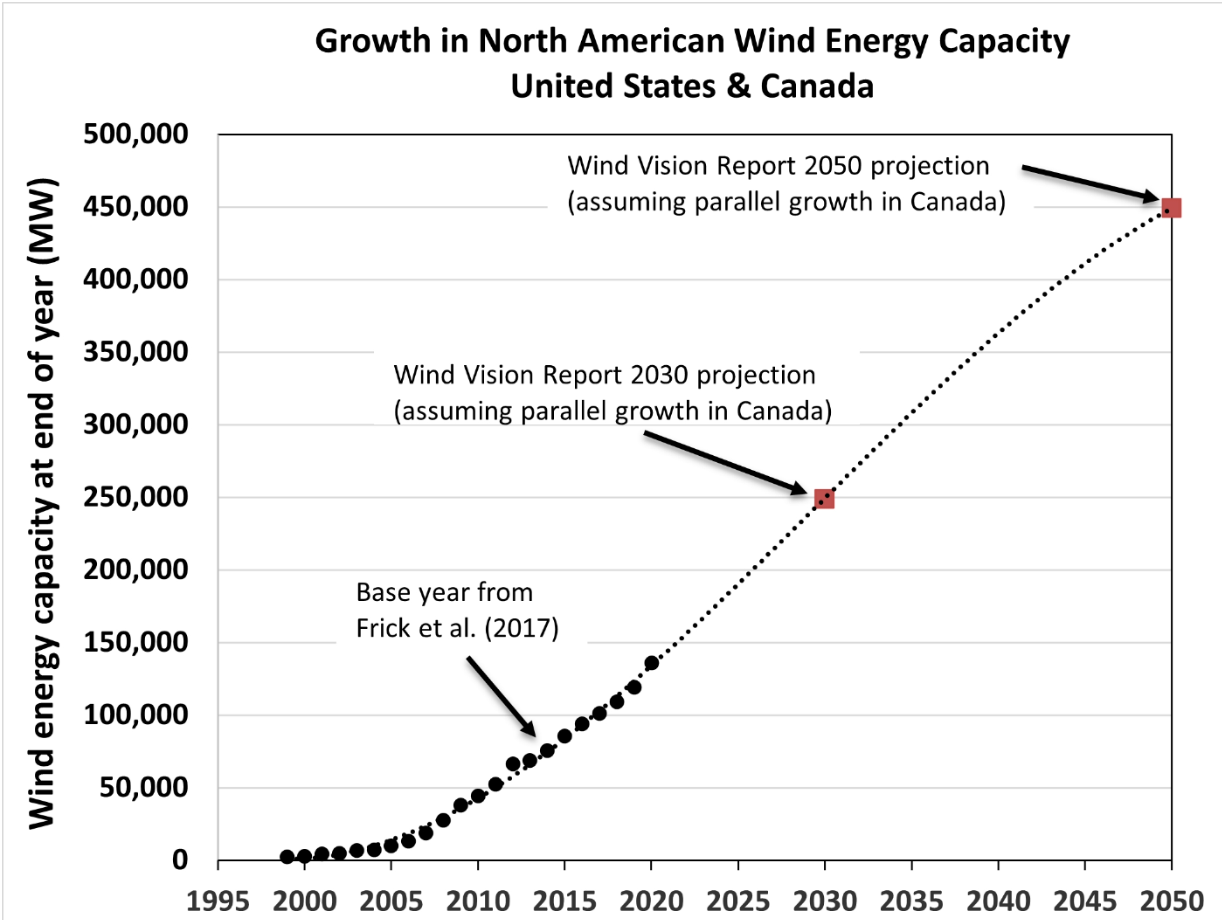

Figure 5. Combined historical and projected wind energy capacity build-out. Data collected from Wind Vision for the United States and Canada, assuming the same market share for Canada for 2030 and 2050 as seen in 2020 (USDOE 2015).

Although annual fatality estimates vary, on average approximately 500,000 bats per year are killed by wind turbines in the USA and Canada (Allison *et al.* 2019). Given the substantial increase in installed capacity since the various cumulative estimates were published (e.g., Arnett and Baerwald 2013), current projections of fatality rates are likely gross underestimates.

Predicting the impact of turbines on bats in the future is confounded in part by mitigation measures. Most bats are killed at night during autumn migration when wind speeds are low (below 6 m/sec). Therefore, if turbine blades do not rotate in these conditions (i.e., they are curtailed), bat fatalities can be reduced by approximately 50% (Baerwald *et al.* 2009; Arnett *et al.* 2011; Smallwood *et al.* 2020). In Ontario, turbines are curtailed when fatality rates exceed a threshold of >10 bats/turbine/yr (OMNR 2011). Policy about curtailment to reduce bat fatalities while minimizing lost energy production is still being developed. In this approach, real-time bat activity data, combined with data on environmental parameters such as wind speed and temperature, are used to adaptively manage turbine operation to avoid bat fatalities. In Wisconsin, curtailment resulted in an

81.4% reduction in Hoary Bat fatalities relative to control turbines with relatively small (≤ 3.2%) losses in energy production and revenue (Hayes *et al.* 2019). Ultrasonic acoustic deterrents may also effectively reduce some bat species' fatality rates at some locations, but more research is needed into the generality of their effectiveness (Weaver *et al.* 2020).

If all wind turbines across Canada and the USA curtailed turbines at wind speeds sufficient to reduce Hoary Bat fatalities by 50% (~5.5 m/sec), and if the starting population size was the "most likely" value of 2.25 million, then the probability of a 50% decline in population size of Hoary Bats would exceed 99% by 2038 (EPRI 2020). If the populations were much larger, for example 10 million, by 2050, the risk of a 50% decline in population size would decrease by 16% relative to full build-out with no mitigations, but 45% higher than baseline declines with no turbines. A 50% reduction in Hoary Bat fatality rates delays but does not wholly avoid extinction risk (EPRI 2020). For example, at a small starting population (1 million), the median year of extinction risk was delayed eight years to 2041, and their probability of extinction was 94% in 2050 (EPRI 2020). Thus, even if the entire existing and future wind energy installations reduced fatalities by 50%, Hoary Bat populations would continue to decline precipitously, and extinction risk would not be eliminated; it would simply be delayed.

The Hoary Bat is the bat species most frequently killed by wind turbines in North America. In the USA, these bats have been recovered at over 95% of sites that have provided data (AWWI 2018). Overall, they make up an estimated 39% of all bat fatalities in North America (Arnett and Baerwald 2013), but this varies temporally and spatially. For example, in Alberta from 2005 to 2007, Hoary Bats made up 60% and Silver-haired Bats 40% of bat fatalities, but those proportions have now switched, and Hoary Bats now account for 40% of bat fatalities (Baerwald and Barclay 2009; Bird Studies Canada Database). Across Canada, 34% of all fatalities involve Hoary Bats (Zimmerling and Francis 2016) and across the USA they represent 32% (AWWI 2018).

Eastern Red Bats are the second most often killed bat species at wind energy facilities across North America, representing 22% of fatalities (Arnett and Baerwald 2013). In Canada, Eastern Red Bats make up 15% of fatalities (Zimmerling and Francis 2016). Fatalities across North America likely exceed 100,000 individuals annually and have been projected to increase as new wind energy projects are developed (Arnett and Baerwald 2013).

Silver-haired Bats also suffer high fatalities at wind energy facilities. They are the third most frequently killed by wind turbines across North America (Arnett and Baerwald 2013). Across North America, Silver-haired Bats make up 18.4% of all bat fatalities, and in Canada, this figure is 25% (Arnett and Baerwald 2013; Zimmerling and Francis 2016) Fatalities across North America likely exceed 100,000 individuals annually and are projected to increase as new wind energy projects are developed (Arnett and Baerwald 2013).

Scope:

It is likely that 71% to 100% (pervasive) of all Hoary Bats in Canada will encounter a wind turbine in the next three generations. For Eastern Red Bats and Silver-haired Bats, it is estimated that 31% to 70% (large) of these bats will likely encounter a wind turbine during the same time frame.

Severity:

The severity of the population declines for bats that encounter wind turbines in the next three generations is expected to be similar for all three species, with a 31% to 100% population decline (extreme – serious for Hoary Bats and serious or 31% to 70% population decline for the other two species) forecast as a result of these encounters.

<u>Decline in Prey Availability – Medium to High Impact</u>

Threat 7.3 – Other Ecosystem Modifications

Aspects of various IUCN threats categories (e.g., 1.0, 2.0, 9.0, 11.0) result in declines of aerial insects—prey required by Hoary Bats, Eastern Red Bats, and Silver-haired Bats. As proximate causes, they are grouped together in this report under Threat 7.3 (Other Ecosystem Modifications) and the threat of prey decline is not accounted for separately in each of these threat categories.

Description of threat:

Globally, insect populations are in dramatic decline in both diversity (extinctions) and abundance (biomass; Leather 2017; Hallmann *et al.* 2017; Goulson 2019; Sánchez-Bayo and Wyckhuys 2019; Cardoso *et al.* 2020; van der Sluijs 2020; Wagner *et al.* 2021). Causes for these declines are multifactorial and cumulative. The main drivers likely include loss of insect-producing habitats such as wetlands, riparian areas, and grasslands due to land conversion for urban, commercial, and agricultural developments (Threats 1.1, 1.2, and 2.1), widespread use of pesticides to control agricultural, forestry, and urban pests (Threat 9.0), and perhaps climate change exacerbating the other drivers (Threat 11.0).

Intensification of land use for agriculture has been implicated as a major cause of worldwide declines in insects, including lepidopterans (Sánchez-Bayo and Wyckhuys 2019), which are important prey for bats (Barclay 1985; Reimer *et al.* 2010). Agriculture is a major cause of the loss of wetlands (Zedler and Kercher 2005). Wetlands are important resources as they support aquatic insects that are important prey (Rolseth *et al.* 1994; Reimer *et al.* 2018) and they provide drinking water. Natural grasslands are also important insect-producing habitats, as are riparian areas, and their conversion or degradation as a result of land development reduces insect prey for bats. Overgrazing by livestock also reduces prey for bats, as insect diversity increases the longer pastures are left ungrazed (Kruess and Tscharntke 2002), and insect abundance can be 4–10 times greater in ungrazed versus grazed pastures (Rambo and Faeth 1999). The net effect to these migratory bats is a loss of diversity and abundance of aerial prey with increasing intensity of grazing.

Reduced insect abundance and diversity resulting from pesticides may also deplete prey available for bats. Moths are important prey of migratory bats and larval moths are a common agricultural pest, and thus have the potential to be treated using insecticides. Insecticides are likely to reduce both target and non-target lepidopteran species. For example, large areas of forest are treated with *Btk*, a bacterium used to control forest pests. Neonicotinoid pesticides have been implicated as a cause of declining butterfly populations (Forister *et al.* 2016). Contamination of aquatic ecosystems in agricultural areas by neonicotinoid pesticides in runoff is common, and has been associated with decreased abundance and diversity of aquatic insects (Morrissey *et al.* 2015; Sánchez-Bayo *et al.* 2016). Although migratory bats commonly feed on moths, emergent aquatic insects such as odonates (dragonflies) and water boatmen may also be important components of their diet (Rolseth *et al.* 1994; Reimer *et al.* 2010).

Scope:

The scope of the loss of insect prey to these bat species is 71% to 100% (pervasive) during the next 10 years, and likely skewed to the high end of this range because insect decline is a global phenomenon and a cumulative effect of many factors. As such, this threat is continental in scope including their breeding grounds, during migration at key stopover sites, and on their wintering grounds (primarily in the United States).

Severity:

It is difficult to estimate the severity of the loss of insect prey to these bat species. However, based on other (avian) aerial insectivores in North America, severity is likely high for bats despite being difficult to quantify using trends in data. For all three species, severity is estimated at 11% to 70% (serious - moderate) over the next three generations, and should likely fall on the lower end of that range in the next 10 years.

<u>Pollution – Low to Medium Impact</u>

Threat 9.1 – Household sewage & urban waste water
Threat 9.2 – Industrial and military effluents
Threat 9.3 – Agricultural and forestry effluents
Threat 9.5 – Air-borne pollutants
Threat 9.6 – Excess energy (noise)

Description of threat:

As relatively long-lived consumers of aerial insects, bats are bioaccumulators of toxic substances present in the environment and may be important bioindicators of pollutants (Jones *et al.* 2009; Stahlschmidt and Brühl 2012; Bayat *et al.* 2014; Secord *et al.* 2015; Zukal *et al.* 2015; Becker *et al.* 2018; Torquetti *et al.* 2021). All insectivorous bats in North America are exposed to a host of contaminants (Secord *et al.* 2015), which can be from both local sources (e.g., O’Shea *et al.* 2001; Little *et al.* 2015a) or broadly distributed through atmospheric deposition (e.g., Chételat *et al.* 2018). Monitoring has focused largely on mercury (Yates *et al.* 2014; Little *et al.* 2015a,b; Becker *et al.* 2018; Chételat *et al.* 2018), other heavy metals (Hickey *et al.* 2001; Zocche *et al.* 2010; Zukal *et al.* 2015), pesticides (Geluso 1976; Eidels *et al.* 2013; Eidels *et al.* 2016; Torquetti *et al.* 2021), and various organic contaminants (Pybus *et al.* 1986; Bayat *et al.* 2014; O'Shea *et al.* 2016).

Several characteristics of bats make it likely that they are sensitive to environmental contaminants (Secord *et al.* 2015). Their high metabolism requires consumption of large volumes of insect prey, and since they are potentially long-lived species, there is a prolonged time for toxins to bioaccumulate. Bats drinking from various water sources could be exposed to pollutants from runoff or in water held in industrial holding ponds. Migratory bats may be more exposed to pollution across large portions of the continent because of their long-distance movements.

Toxic levels of organochlorines (e.g., dieldrin, polychlorinated biphenyl, DDT, DDE) derived from insect-pest spray programs have been recorded in organ tissue in several species of bats (Reidinger 1976). Organochlorines cause fatality in fetuses and newborn Big Brown Bats (Clark and Lamont 1976), and bats are likely more sensitive to DDT than other mammals (Luckens and Davis 1964). Agricultural use of DDT causes mortality in young bats that metabolize fat containing toxic levels of this pesticide, and likely led to drastic declines in Mexican Free-tailed Bats (*Tadarida brasiliensis;* Geluso *et al.* 1976). The application of some chemicals has declined or been banned in Canada and the USA (e.g., DDT) but the impacts of pesticides in use today are not well studied. Almost all (98%) Indiana Bats (*Myotis sodalis*) collected from 2005 to 2007 had detectable levels of organochlorine pesticides in their tissues (Eidels *et al.* 2013). The effect of these pesticides on migratory bats has not been examined directly, but exposure is likely high given that they are a common species in agricultural landscapes and forests where pesticides are commonly applied. Additionally, they may still be exposed to pesticides, such as DDT, on wintering grounds south of the United States.

Agricultural intensification has resulted in increased pesticide use (Main *et al.* 2014). Neonicotinoid insecticides are among the most common currently used classes of insecticides and pose substantial environmental risks (Goulson 2013), including to insectivorous bats (Hsiao *et al.* 2016; Wu *et al.* 2020). They are typically applied as a seed coat for crops such as canola (Main *et al.* 2014). As of 2012, an estimated 44% of prairie cropland was treated with neonicotinoid pesticides (Main *et al.* 2014). This class of pesticide is frequently detected in prairie pothole wetlands in Canada (Main *et al.* 2014), where they are likely to be ingested by bats while drinking or foraging. One neonicotinoid pesticide (imidacloprid) has been shown to impair the spatial memory of an echolocating bat from Asia (Formosan Leaf-nosed Bat; *Hipposideros terasensis*; Hsiao *et al.* 2016). Tests of neonicotinoid pesticides have not been reported for North American bats and it is unclear if exposure levels are high enough to result in toxicological effects sufficient to cause population declines. However, declines in insectivorous birds have been associated with high neonicotinoid concentrations (Hallmann *et al.* 2014).

Eutrophication of aquatic habitat caused by wastewater runoff and other sources may contribute to toxic cyanobacterial blooms (blue-green algae; Michalak *et al.* 2013). Toxic cyanobacterial blooms were implicated in the death of an estimated 1,000 bats in a single event in Alberta (species unknown, but one of six bats examined was a Hoary Bat; Pybus *et al.* 1986). Drinking water may also be degraded because of inputs from urban and industrial sources. Several common contaminants with the potential to disrupt bats' physiological systems have been detected in carcasses in the northeastern United States, including substances found in pharmaceutical and personal care products (Secord *et al.* 2015). Mass mortality events have also been associated with bats drinking from industrial holding ponds, including cyanide ponds used for gold mining and crude oil pits (Flickinger and Bunck 1987; O'Shea *et al.* 2016).

In Ontario and Quebec, Hickey *et al.* (2001) found elevated levels of mercury, zinc, selenium, and lead in Little Brown Myotis, and mercury and zinc in Northern Myotis (*Myotis septentrionalis*). The levels of mercury were high enough to cause sublethal biological effects. Methylmercury toxicity primarily effects the brain and can cause neurological and behavioural effects at sublethal exposure levels (Chételat *et al.* 2018). Bats likely ingest heavy metals by feeding on insects (e.g., Trichoptera) that emerge from metal-laden sediments in agricultural areas. However, some heavy metals, such as mercury and lead, may also originate from distant point sources and atmospheric deposition (Chételat *et al.* 2018).

Noise pollution is also a threat. Bats rely on echolocation to orient and detect prey. Anthropogenic noise constitutes a major source of ambient noise above background levels and can result in bats altering their echolocation calls (Hage and Metzner 2013) and nightly emergence patterns (Shirley *et al.* 2001), avoiding potential foraging areas (Schaub *et al.* 2006; Siemers and Schaub 2011; Bennet and Zurcher 2012), and being unable to effectively drink and feed (Bunkley and Barber 2015; Domer *et al.* 2021). For example, loud music broadcast near bat roosts and foraging areas affected emergence times (Shirley *et al.* 2001), reduced time spent foraging and disrupted drinking and foraging (Domer *et al.* 2021). Noise from gas compressors reduced nightly activity by some bat species up to 40%, particularly those that use low frequency (<35 kHz) echolocation calls (Bunkley *et al.* 2015), such as Hoary Bats. Further, noise from natural gas compressor stations increased the time required by Pallid Bats (*Antrozous pallidus*) to locate prey (Bunkley and Barber 2015). Conversely, aircraft noise did not alter the activity of Long-tailed Bats (*Chalinolobus tuberculatus*; Le Roux and Waas 2012).

Roads are among the largest sources of anthropogenic noise encountered by bats. Noise from road traffic may affect social communication (Jiang *et al.* 2019), activity levels (Finch *et al.* 2020), and bats' ability to locate prey (Bunkley and Barber 2015), and may cause foraging bats to avoid areas near roads (Bennet and Zurcher 2012). In northern California wetlands, Hoary and Silver-haired Bat activity was up to three times greater 300 m away from a major road than along it (Kitzes and Merenlander 2014). Thus, the impact of major roads may constitute functional habitat loss for these species. However, the impact on migratory bats is likely low, given that much of their range is in relatively road-less areas.

Scope:

Given that some chemical and noise pollution is widespread across the distributional range of these species, it is estimated overall that 31% to 100% of individual bats (pervasive, pervasive-large) will be exposed to these pollutants over the next 10 years.

Severity:

Despite the scope of chemical and noise pollution for these bats, there is considerable uncertainty about the severity of this threat to bats (moderate-slight), as research is sparse. Nevertheless, alarming rates of some of these pollutants or contaminants have been reported as well as sublethal effects. Anthropogenic noise is ubiquitous and increasing.

Loss of Roosting Habitat – Low Impact

Threat 1.1 – Housing and urban areas
Threat 1.2 – Commercial and industrial areas
Threat 2.1 – Annual and perennial non-timber crops
Threat 5.3 – Logging and wood harvesting
Threat 7.1 – Fire and fire suppression

Aspects of all of the above IUCN threat categories result in loss of roosting habitat for Hoary Bat, Eastern Red Bat, and Silver-haired Bat. While the overall cumulative threat impact of loss of roost trees is expected to be low, they are accounted for separately in the threats calculator for each species (Appendices 1–3).

Description of threat:

Habitat for bats consists of winter habitat, summer foraging and drinking habitat, summer roost structures, and, for migratory species, migration routes, and stopover sites (see **Habitat Section**). Roosting habitat is among the most important, and possibly limiting, for bats (Fenton 1997). Conversion of natural forest and woodland habitats due to resource extraction activities (e.g., logging, mining, and others), as well as residential, commercial, and industrial developments, and forest fires and fire suppression activities, reduces the number of potential roost trees for these species.

Urban population growth in Canada is on the order of 1.5% per annum. Development of new housing and urban areas (Threat 1.1) as well as commercial and industrial areas (Threat 1.2) to support this growth requires clearing in forested environments. The net impact is a loss of roosting areas for tree-roosting bats. Mitigation includes urban forestry projects in many Canadian towns and cities. However, the extent of such initiatives is not well quantified. Moreover, it will likely take decades before trees planted in urban and commercial areas become suitable for roosting. In Chicago, Eastern Red Bat and Silver-haired Bat activity increased in restored urban woodlands (Smith and Gehrt 2010).

Agriculture (Threat 2.1) can also dramatically reduce roosting habitat. Since European settlement, cultivation of native habitats for agriculture has resulted in substantial loss of roosting habitat for all three bats across North America. Sites where agriculture is most concentrated are also those where trees are most likely to be limiting. In western Canada, for example, agricultural land is also increasingly being converted for urban and rural residential uses. As agricultural land is lost to urbanization and rural developments, new areas, primarily in previously forested areas, are converted to agriculture (Haarsma 2014). This change also coincides with intensification of existing agricultural lands. More intensive agricultural production methods frequently result in fewer bats (Kalda *et al.* 2015; Monck-Whipp *et al.* 2018; Put *et al.* 2018). For example, within agricultural landscapes, Hoary Bats are more abundant in areas with a greater diversity of crops and in smaller fields (Monck-Whipp *et al.* 2018). Loss of treed shelterbelts, which often occurs to make room for larger equipment when converting to cropland (Rempel *et al.* 2017), may result in losses of tree cover needed for roosting and of edge habitats used for foraging and commuting (Boughey *et al.* 2011; Jantzen and Fenton 2013).

The forest structures most associated with roosting by these three species of bats are likely numerous and difficult to identify. Forestry practices (Threat 5.3) reduce the abundance of potential roosting trees for these bats. Declines in the amount of older-aged classes of forests (i.e., late successional, “old-growth”) could be a threat if these forests are preferentially used for roosting (Crampton and Barclay 1998; Jung *et al.* 1999). Alternatively, clear-cut harvesting creates edge habitat that is widely used for foraging by bats, and forest harvest practices that create forest remnants in harvested areas and involve partial-cut harvesting may mitigate impacts of forestry, especially for Eastern Red Bats (Hogberg *et al.* 2002; Morris *et al.* 2010). For example, Hoary Bats were detected significantly more often in edge habitats than in any other forest habitat in North Carolina (Morris *et al.* 2010). Overall, the extent of habitat loss (or gain) cannot be quantified because of these species’ large range and the varied intensity of forest harvest practices across the range.

Forest fires (Threat 7.1) that kill mature timber may allow for the generation of cavities, which could benefit Silver-haired Bats over the short-medium term. However, large-scale “megafires” dramatically reduce the density of large live and dead trees (Buchalski *et al.* 2013; Jung 2020) that are preferentially used by these species (Mager and Nelson 2001; Elmore *et al.* 2004; Kalcounis-Ruppell *et al.* 2005; Willis and Brigham 2005; Limpert *et al.* 2007; Perry and Thill 2007; Klug *et al.* 2012; Bohn 2017). Some individuals are also likely susceptible to the direct effects of fire (i.e., mortality), as well as indirect effects that fire has on habitat (e.g., loss of cover and food). Fire suppression activities often focus on dead or dying trees, reducing local abundance, which may affect Silver-haired Bat as they rely on these types of trees as roosts (Bohn 2017).

Unlike the other two species, Silver-haired Bats use cavities. Thus, forest harvesting is likely a greater threat for them. Like most cavity-roosting bats, they appear to prefer cavities in larger, older trees (Betts 1998b; Kalcounis-Ruppell *et al.* 2005; Bohn 2017). There is also likely to be some direct mortality due to tree felling if it occurs during the summer months. Logging in British Columbia is considered a significant threat to the availability of roosting trees for Silver-haired Bats, because of the conversion of old forest to younger stands and the associated loss of large trees (Kellner pers. comm. 2020). Given that both Eastern Red Bats and Hoary Bats are solitary foliage-roosters, they are likely to also be affected by forest harvesting. Roosting opportunities for both species may be improving in eastern Canada, where deciduous forests are recovering in many places.

Migratory bats spend most of the year outside of Canada (Cryan 2003). They will be affected by changes in land use along migration routes and in their winter range, which likely includes the coastal United States and possibly Mexico (Cryan and Veilleux 2007; Cryan *et al.* 2014b). Loss of tree cover in overwintering grounds is potentially detrimental (Cryan and Veilleux 2007). In California, forest cover declined by approximately 4.1% from 1973 to 2000, with most of this loss occurring during the latter part of that time period (Sleeter *et al.* 2013). Forest loss in coastal areas has outpaced loss in other regions of that state. Across the United States, forest loss was estimated at 4.2% between 1973 and 2000, similar to that observed in California (Sleeter *et al.* 2013).

Scope:

Many bats will face reduced roosting opportunities over the next three generations due to land clearing for agriculture, forestry, and residential and commercial developments. While it is difficult to estimate the extent of this scope, it ranged from negligible to large for various threats. Much of the winter range for all three bats will also be affected. Large areas of intact forest remain, particularly in the boreal forest and mountainous areas.

Severity:

It is difficult to predict the severity of loss of roosting opportunities. This loss was considered one of the main threats to forest-dwelling bats (Fenton 1997) prior to the new, emerging threats of disease, wind turbines, and insect loss. However, the overall decline in bat populations over the short-term is likely moderate to slight.

<u>Climate Change – Unknown</u>

11.1 – Habitat shifting and alteration
11.2 – Droughts
11.3 – Temperature extremes
11.4 – Storms and flooding

Description of threat:

The effects of climate change on these migratory bat species are mostly unknown. Individuals of all three species are presumed to undergo long-distance movements (greater than 1,000 km) and have potential to be affected by changes occurring across vast regions. It is unknown how adaptable the species may be to climate change. However, climate change has the potential to affect bats through a combination of reduced prey availability, loss of tree cover, and a reduction in drinking habitat (Adams and Hayes 2008; Jones and

Rebelo 2013; Schneider 2013). Rising temperatures may affect energy balances by altering the efficacy of torpor and hibernation, increasing the need for water, and desynchronizing insect emergence with seasonal distributions, resulting in a phenological mismatch (Valdez and Cryan 2009; Jones and Rebelo 2013). Climate change is likely increasing the frequency and severity of wildfires (Abatzoglou and Williams 2016; Goss *et al.* 2020), which affects both summer habitat in the boreal forest (Jung 2020) and winter habitat in the USA (e.g., California; Weller *et al.* 2016). Although wildfire may be followed by a gradual improvement in foraging habitat (Jung 2020), the initial effects of wildfire on bats is poorly understood. Climate change is likely generating periods of weather phenomena (e.g., storms and increased summer temperatures [e.g., heat domes]). Noakes *et al.* (2021) found that adult Hoary Bats were better able to cope with temperatures of ~42°C compared to Little Brown Myotis and Silver-haired Bats.

Under some models, climate change is predicted to decrease wetland cover, especially in arid environments, and cause a northward expansion of arid environments into the boreal forest (Schneider 2013). Aspen forests may experience dieback because of increased drought associated with warmer and drier climates, potentially leading to an expansion of grassland and parkland habitats (Hogg *et al.* 2002; Michaelian *et al.* 2011; Schneider 2013). The loss of aspen forest in areas that currently have parkland or grassland climates will likely reduce habitat suitability for migratory bats given the importance of tree cover for foraging and roosting (Holloway and Barclay 2000). However, the effect of predicted expansion of parkland habitats into the boreal forest on migratory species is less clear because some of these species may prefer aspen-parkland-like habitats (Lausen and Barclay 2006; Baerwald *et al.* 2014).

Potential benefits of climate change are also possible. For example, under some conditions, warmer temperatures may reduce energy requirements for bats needing to maintain elevated (homeothermic) body temperatures, and warmer temperatures prolong the period when insects are active, both of which may result in greater survival and reproductive success (Lewis 1993). It may also allow some species of bats to shift their distributional range northward (Humphries *et al.* 2002).

Scope:

All individuals of these three species (100%; pervasive) are expected to be affected by climate change in the coming decades (including the next 10 years).

Severity:

It is not clear how climate change will affect bats in the short term (three generations), or even if the net effect will be positive or negative. As such, the severity of climate change in the next 10 years for all three of these bat species is unknown.

Limiting Factors

Limiting factors are not human-induced and make it difficult for a species to respond to recovery or conservation efforts (B.C. Ministry of Environment 2016; Environment and Climate Change Canada 2018). These factors are generally not well known for bats in Canada.

Long-distance migration is a risky strategy (Alerstam *et al*. 2003; Seidler *et al.* 2015). The frequency of natural accidents and other mortality events (e.g., starvation, predation) experienced by these bats during their twice annual migrations are unknown, but may be a significant cause of mortality (Johnson 1933; Manville 1963; O'Shea *et al.* 2016). Accidents that occur during migration are likely to be limiting factors to population growth.

Other limiting factors for these bats are similar to those for all bats in Canada, and include inclement weather and storms, as well as natural predation. Poor weather and storms may result in mortality events or reductions in time spent foraging. Additionally, cool, rainy spring weather may delay gestation and parturition because pregnant females make more extensive use of torpor and forgo feeding on some evenings (Willis *et al.* 2006). Natural predation by snakes, birds, and mammals may also limit population growth. Predation rates on these bats are not known, but likely low. Of note, Hoary Bats and Eastern Red Bats may be particularly susceptible to predation and the impact of storms because they roost out in the open, unlike other bats in Canada, including Silver-haired Bats, which seek refuge within trees, under exfoliating bark, or within human infrastructure (e.g., buildings, bridges).

Despite being widespread, Hoary Bats, Eastern Red Bats, and to a lesser extent, Silver-haired Bats, are relatively rare species in studies of bat communities in Canada, often representing <5% of detections per species in acoustic studies (e.g., Crampton and Barclay 1998; Jung *et al.* 1999; Kalcounis *et al.* 1999; Broders *et al.* 2003; Coleman and Barclay 2012; Luszcz and Barclay 2016). As such, local population sizes are assumed to be particularly small relative to other species in bat assemblages, which may limit population growth and persistence.

Naturally occurring diseases may also be a limiting factor for some bats. Lasiurine bats are believed to be particularly susceptible to rabies, for example, compared to other species of Canadian bats, but some evidence suggests otherwise (Klug *et al.* 2011).

Silver-haired Bats are the only species of the three known to overwinter in Canada, and winter habitat may be limited to the southernmost regions of British Columbia. It is unknown if available overwintering sites with suitable microclimatic conditions are limiting in Canada.

Compared to other bats in Canada, migratory tree bats are relatively fecund. Hoary Bats and Silver-haired Bats often have twins (Kunz 1982; Shump and Shump 1982a), while of Eastern Red Bats may have a litter size of 1 to 4 pups (Shump and Shump 1982b), which is exceptional for a vespertilionid. Larger litter sizes may provide a buffer for low pup survival within or between years, and make populations more resilient to localized threats or limiting factors. However, their mating strategies seem to rely on solitary males and females, who have been sexually segregated over the summer and will continue to do so overwinter, finding each other along extensive and dispersed migratory routes to mate, leading to potential Allee effects as mates become increasingly hard to find in declining populations.

Number of Locations

The number of locations for Hoary Bats, Eastern Red Bats, and Silver-haired Bats is unknown, but certainly much greater than ten. All three species have broad ranges that span much of North America. They all face many potential threats across this range, with the greatest threat being wind energy development, followed by loss of insect prey and, to a lesser extent, chemical pollution. These threats occur on a myriad of private and public lands, interact to various degrees on local bat populations, and are not easily reversible at a continental scale. It is inferred that as the populations of these species decline, eventually the number of locations will as well. However, the number of locations will likely remain numerous for the next 10 years.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

None of these three species of bats are listed or protected under federal, provincial, territorial or state species at risk legislation on their breeding grounds in Canada or their wintering grounds in the United States or Mexico, with the exception of Quebec. In Quebec, the three species are included on the Liste des espèces susceptibles d’être désignées menacées ou vulnérables (list of wildlife species likely to be designated threatened or vulnerable) produced according to the "Loi sur les espèces menacées ou vulnérables" (RLRQ, c E-12.01) (LEMV) (Act respecting threatened or vulnerable species) (CQLR, c E-12.01). All three species of bats are afforded general protections from harm under provincial and territorial wildlife acts, as are most other species.

Non-Legal Status and Ranks

<u>Global</u>

The IUCN Red List ranks Hoary Bats as *Least Concern*, based on an assessment completed in 2015 (Gonzalez *et al.* 2016; Table 1). However, the population trend is noted as unknown and the only global threats mentioned are deforestation and human disturbance in Mexico. Wind turbines and insect declines were not included as threats. Eastern Red Bats were also assessed as *Least Concern* in 2015, with the justification being that they are “widespread in distribution, presumed large population, occurrence in protected areas, tolerance to some degree of habitat modification, and because it is unlikely to be declining at nearly the rate required for listing in a threatened category”

(Arroyo-Cabrales *et al.* 2016). The global population trend was considered stable. No threats were considered in the IUCN Red List assessments of either Eastern Red Bats or Silver-haired Bats. Silver-haired Bats were also assessed in the IUCN Red List as *Least Concern*, but more recently, in 2018 (Solari 2019). The justification for this assessment is the same as that for Eastern Red Bats (Arroyo-Cabrales *et al.* 2016), with the population trend considered stable. Threats considered in the global assessment of Silver-haired Bats were considered of low impact and restricted to forest clearing reducing available roosting sites.

In contrast to the IUCN Red List status assessments, the 2020 rounded global rank (G Rank) for each of these three bat species in North America north of Mexico by NatureServe is G3 (*Vulnerable;* NatureServe Explorer 2020a,b,c; Table 1). These global ranks were determined using a rank calculator (Cannings, pers. comm. 2020). Short-term (3 generations) declines are estimated on the order of <30% (Hoary Bat) and 10% to 50% (Eastern Red Bat and Silver-haired Bat), while long-term declines (since European Settlement) are estimated as 10% to 50% (Hoary Bat and Silver-haired Bat) and 10% to 70% (Eastern Red Bat). Identified threats for all three species include fatalities at wind turbines, declines in insect prey, and historical and ongoing deforestation (NatureServe Explorer 2020a,b,c).

Table 1. Global conservation ranks for Hoary Bat, Eastern Red Bat, and Silver-haired Bat. Sources: Gonzalez et al. 2016; Arroyo-Cabrales *et al*. 2016; Solari 2019; NatureServe 2022a,b,c; CMS 2022)

Country / Province or Territory or State	Rank or Listing		
	Hoary Bat	Eastern Red Bat	Silver-haired Bat
Global			
IUCN Red List	Least Concern (2016)	Least Concern (2016)	Least Concern (2019)
NatureServe G Rank	G3 - Vulnerable (2020)	G3 - Vulnerable (2020)	G3 - Vulnerable (2020)
Convention on the International Trade in Endangered Species (CITES)	–	–	–
Convention on the Conservation of Migratory Species of Wild Animals	Appendix II (2020)	Appendix II (2020)	–

Neither Hoary Bats, Eastern Red Bats, nor Silver-haired Bats are listed in the Convention on the International Trade in Endangered Species (CITES; Table 1). The criteria for inclusion in the appendices of CITES include the risk of endangerment from international trade (Possingham *et al.* 2002; Reeve 2006; Challender *et al.* 2015), but no such trade is known to occur for these species.

Hoary Bats and Eastern Red Bats (but not Silver-haired Bats) were recently (2017) listed in Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS; also known as the Bonn Convention; Table 1). The 1979 CMS has two primary objectives. First, to protect migratory species threatened with extinction and, second, to encourage cooperation by range states in conserving migratory species that would benefit from international cooperation (Lyster 1989; Trouwborst 2012). For a species to be listed under Appendix II of the CMS, it must have an “unfavourable conservation status” and require international cooperation for its conservation. Range states are encouraged to complete international agreements to benefit these species.

National

The national (N rank) for Hoary Bats in Canada by NatureServe is N5B, NUM (NatureServe Explorer 2020a; Table 2); that is the breeding population is assessed as *Secure*, while the status of the migratory population is *Undetermined*. Comparatively, the N Rank for the United States does not distinguish between breeding and migratory populations and is N5 (*Secure*). Moreover, the N Ranks in Canada and the United States are currently (2020) not aligned with the G Ranks for all three species; that is, the G Rank is of higher concern than both N Ranks.

Table 2. NatureServe national (N) and subnational (S) ranks for Hoary Bat, Eastern Red Bat, and Silver-haired Bat across their distributional range in Canada and the United States (NatureServe Explorer 2020a,b,c).

Country / Province or Territory or State	NatureServe S Rank		
	Hoary Bat	Eastern Red Bat	Silver-haired Bat
Canada	N5B, NUM	N5B, NUM	N5B, NUM
Alberta	S3B	S3B	S3S4B
British Columbia	S4S5	SU	S4S5
Island of Newfoundland	SNA	–	–
Manitoba	S3B	S3B	S3S4B
New Brunswick	SUB,S2?M	SUB,S2?M	SUB,S1?M
Northwest Territories	SU	–	SU
Nova Scotia	S1S2B,S1M	S1S2B,S1M	SUB,S1M

Country / Province or Territory or State	NatureServe S Rank		
	Hoary Bat	Eastern Red Bat	Silver-haired Bat
Nunavut	S5B,SNRM	SNR	–
Ontario	S4	S4	S4
Quebec	S3	S3	S3
Saskatchewan	S5B	S4B	S5B
Yukon	SUB	–	SNR
USA	N5	N5	N3N4
Alabama	SNR	S5	SNR
Alaska	–	–	S4
Arizona	S4	SNR	S3S4
Arkansas	S3	S5	S3N
California	S4	–	S3S4
Colorado	S3S4B	S2S3B	S3S4
Connecticut	S3B	S3B	S3B
Delaware	–	S5	SU
District of Columbia	S2N	S4	S4N
Florida	SU	SNR	SNR
Georgia	S4	S5	S5
Hawaii	SNR	–	–
Idaho	S3	–	S3
Illinois	S4	S5	S3S4
Indiana	–	S4	SNRN
Iowa	S4	S4	S4
Kansas	S4B	S5B	SNA
Kentucky	S3S4M	S5	S4S5M
Louisiana	S4	S4	SNA
Maine	SU	SU	SU
Maryland	S3S4	S3S4	SU
Massachusetts	S2	S3	S2
Michigan	S5	S5	S5

Country / Province or Territory or State	NatureServe S Rank		
	Hoary Bat	Eastern Red Bat	Silver-haired Bat
Minnesota	–	–	SNR
Mississippi	S2?	S4S5	–
Missouri	S3	S4	S3
Montana	S3	S3	S4
Nebraska	S3	S3	S3
Nevada	S2S3	–	S3
New Hampshire	S3B	S3?B	S3B
New Jersey	S3	S3	S3
New Mexico	S4	S3N	S4
New York	S3S4B	S3S4B	S2S3B
North Carolina	S3S4	S5	S4
North Dakota	SNR	SNR	SNR
Ohio	S3	SNR	SNR
Oklahoma	–	SNR	S2
Oregon	–	–	S3S4
Pennsylvania	S4	S4	S1
Rhode Island	S1	SNR	SU
South Carolina	SNR	S4S5	SNR
South Dakota	S5	S5	S4
Tennessee	S5	S5	S4S5
Texas	S4	S4	S4
Utah	S4B	SNR	S4B
Vermont	S3B	S4B	S2B
Virginia	SUB,S3M	S4	SUB,S4N
Washington	S3S4	–	S3S4
West Virginia	S3	S3	S2
Wisconsin	S3	S3	S3
Wyoming	S4	S3B	S3B

The NatureServe N rank for Eastern Red Bats is N4B, NUM that is the breeding population is assessed as *Apparently Secure*, while the status of the migratory population is *Undetermined* (NatureServe Explorer 2020b; Table 2), as well as the associated issues identified above.

For Silver-haired Bats, the NatureServe N rank for Canada is the same as for the other two bats above (N5B, NUM; NatureServe Explorer 2020c), which does not align with the G rank. However, the N rank for the United States is N3N4, and in agreement with the G rank.

<u>Subnational</u>

The status of each of these three bat species assessed in each province, territory, or state (S Ranks) is variable (NatureServe Explorer 2020a,b,c; Table 2), likely reflecting more about the state of knowledge about these species in each jurisdiction rather than their actual conservation status.

In Canada, Hoary Bat was *Not Assessed*, *Not Ranked*, or its status is *Undetermined* for New Brunswick, Northwest Territories, Nunavut (migratory only), Yukon, and the island of Newfoundland. No rank is available for Labrador. Complicating matters, some provinces and territories report S Ranks for breeding and/or migratory populations, while others provide a single S Rank with no information on whether it pertains to breeding or migratory populations. Similar variation and discrepancies are apparent in the S ranks for Eastern Red Bats and Silver-haired Bats (Table 2)

Habitat Protection and Ownership

Survey effort for bats is sparse across national, provincial, and territorial parks, and other protected areas in Canada. All three species of migratory bats are widespread and likely found seasonally in >100 protected areas found below 62–63°N west of Hudson Bay, and below about 54°N east of Hudson Bay in Canada, the USA, and Mexico. Despite the large number of protected areas where these three bats are found across their large distributional ranges, it is unknown if the existing protected area network alone meets their habitat needs.

Only the province of Quebec has developed a recovery plan for any of the three migratory species (Équipe de Rétablissement des Chauves Souris du Québec 2021). The plan is for Eastern Red Bat and has objectives to evaluate and mitigate threats, conduct monitoring and research to facilitate recovery, and raise awareness with the public and stakeholders.

ACKNOWLEDGEMENTS

This report was written with input from numerous researchers and managers involved with migratory bats in North America.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Erin Baerwald is an Assistant Professor in the Ecosystem Science and Management Program at the University of Northern British Columbia where she teaches courses in Animal Behaviour, Conservation Biology, and Wildlife Management. She is also an internationally recognized expert on the impacts of wind energy on migratory bats, a member of the Terrestrial Mammals Species Specialist Committee and the IUCN bat specialist group, and a migratory bat expert for the United Nation's Convention on the Conservation of Migratory Species of Wild Animals (CMS). In this capacity, she worked with the government of Peru to draft the proposal to list four species of Lasiurine bats under Appendix II of the Convention, which was unanimously accepted by all parties at CMS COP 12. She has co-authored survey protocols for bats and wind energy in Alberta and Saskatchewan and contributed to the USA Fish and Wildlife Service's Land-Based Wind Energy Guidelines. She has published extensively on these species of bats, particularly the Silver-haired Bat and the Hoary Bat, including co-authoring a manuscript on the potential population impacts of wind energy on Hoary Bats.

Robert Barclay is a Professor in the Biological Sciences Department of the University of Calgary. He teaches courses in introductory biology, ecology, mammalogy, and conservation biology. He has supervised 43 graduate students. Starting with his M.Sc. research in 1978, he has studied the ecology, behaviour, and conservation biology of various animals, primarily bats. He has published over 140 peer-reviewed publications on bats, including 27 specifically on the three species of bats considered by this status report. This research has taken place in Ontario, Manitoba, Alberta, BC, Yukon, and Northwest Territories. He was a member of the IUCN Chiropteran Specialist Group for 10 years, and has been a member of the Scientific Advisory Committee of the Bats and Wind Energy Cooperative (BWEC) since its inception in 2004. He was the elected President of the North American Symposium on Bat Research, and was an Associate Editor of the *Canadian Journal of Zoology* and the *African Bat Conservation News*.

Mark Brigham is a Professor at the University of Regina and has been a faculty member since 1990. Most of his research has focused on bats and nocturnal insect-eating birds (nightjars). He has co-authored over 190 peer reviewed journal articles. His research focuses on ecology, behaviour, and thermal physiology. He is currently one of the two Co-Editors in Chief of the *Canadian Journal of Zoology* and was an Associate Editor of the *Journal of Mammalogy*. He was a member of COSEWIC after being appointed as a terrestrial mammal Co-Chair from 2005 to 2010. This followed a 5-year term as a member of the Terrestrial Mammal Subcommittee. In 2006, he received the Gerritt S. Miller Jr. Award from the North American Society for Bat Research for outstanding lifetime service and contributions. Aside from formal teaching duties, he is a strong proponent of bringing Science and my research to the public and regularly gives "bat talks" to school groups, naturalists and organizations, as well as service clubs. Partly for this, he was awarded the 2008 Joseph Grinnell award by the American Society of Mammalogists for long-term contributions to Education about Mammalogy. He is the only Canadian to have received this award.

Dana Green is a Ph.D. candidate at the University of Regina focusing on the study of migratory bat ecology and biology. She has been working with bats since 2012, and has studied a variety of bat species both in the United States and Canada. Dana earned her M.Sc. in biology from Northern Arizona University and her B.Sc. in wildlife biology from Missouri State University. She has published on a variety of subjects and taxa, with a concentrated effort on behavioural studies within the context of applied conservation. Partnered with her academic career, she has worked with consulting companies on threatened and endangered bat surveys across the midwestern and eastern United States. Dana is currently an elected member of the board of directors for the American Society of Mammalogists and student representative for the North American Society for Bat Research. Along with societal involvement, Dana has done many outreach events including at local schools, summer programs, and for city-wide events.

Thomas Jung has been Yukon Government's Senior Wildlife Biologist since 2001, and Adjunct Professor at the University of Alberta since 2011, where he teaches mammalogy and wildlife management. His work on northern mammals has included species ranging in size from pygmy shrews to polar bears, and has spanned the area from Labrador to Alaska. He has co-authored about 130 peer-reviewed journal articles, including 29 on bats. Tom completed a thesis at McGill University on bat–habitat relationships in the northern Great Lakes region, and has since co-supervised four graduate students working on bats. He is an Associate Editor for the *Journal of Mammalogy* and *Canadian Field-Naturalist*, and was Guest Editor for a special issue of the *Northwestern Naturalist* on bats. He is a member of COSEWIC and RENEW, and coordinates the national general status ranks for Canadian mammals. Tom has participated in national recovery teams for several species at risk (including Little Brown Bats), and led regional conservation planning initiatives for Grizzly Bears, Mountain Caribou, and Wood Bison. He is a member of the IUCN Bison Specialist Group and Co-Chair of the National Bison Technical Advisory Committee, and co-wrote the COSEWIC status report on Bison. Tom serves on conservation-related committees of the American Society of Mammalogists.

Cory Olson is an independent consultant with over 10 years' experience working with bats and other wildlife. He has led numerous bat surveys and research projects in western Canada and has co-authored several reports and guidelines specific to bat conservation and management. He completed a M.Sc. focusing on bats and is registered as a Professional Biologist in Alberta and British Columbia. He currently coordinates the Alberta Bat Conservation Program with Wildlife Conservation Society Canada.

COLLECTIONS EXAMINED

None

Appendix 1. Threat assessment for Hoary Bat in Canada.

THREATS ASSESSMENT WORKSHEET					
Species or Ecosystem Scientific Name	*Lasiurus cinereus*	**Element ID**		**English Name**	Hoary Bat
Version Date:	11-August-2021				
Version Author(s):	Kristiina Ovaska, Stephen Petersen, Erin Baerwald, Mark Brigham, Cory Olson, Fanie Pelletier, Donald Sam, Eve Lamontagne, Audrey Robillard, Thomas Jung, Hayley Roberts, Lynne Burns, Lisa Wilkinson, Kristin Cline, Pierre-Andre Bernier, Adam Grottoli, Courtney Baldo, Dana Green, Jolene Laverty, Emma Pascoe				
References:	COSEWIC status report, draft				
Generation Time:	2-6 years (6 years used by call participants)				

Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	1	0
	B	High	1	1
	C	Medium	1	1
	D	Low	3	4
Calculated Overall Threat Impact:			**Very High**	**High**
Assigned Overall Threat Impact:			**AB = Very High - High**	
Impact Adjustment Reasons:				
Overall Threat Comments			Threats are many and cumulative; however, the overall threat impact is largely driven by the threat of expanding wind energy development. The scope and severity of other potential threats (e.g., disease) are unknown and not estimated.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Moderate - slight	High (continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Slight or 1-10% pop. decline	High (continuing)	New residential and urban developments likely have a mixed effect on Hoary Bats, as loss of trees as roosting habitat will mean some significant areas are no longer suitable. On the other hand, planting trees to provide greener urban areas offsets the net loss of trees to a degree.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Moderate - slight	High (continuing)	Similar to above, but perhaps with less mitigation through planting or retention of trees. Emphasis may be more on loss of wetlands as foraging habitat.
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture	D	Low	Restricted - small	Moderate - slight	High (continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops	D	Low	Restricted - small	Moderate - slight	High (continuing)	Likely varies by region with increasing impact in the west, where conversion of land to agriculture increases, and likely negligible impacts in Ontario eastward, where old field conversion to forest provides increasingly more habitat. Loss of roost trees and wetlands (foraging habitat) are the main impact.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching		Negligible	Large (31-70%)	Negligible or <1% pop. decline	High (continuing)	Overgrazing of riparian areas. Entanglement on barbed wire is also a potential concern, athough the scope is large and occurrences are rare. When entanglement occurs, most cases are likely fatal.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining	AB	Very High - High	Pervasive (71-100%)	Extreme - serious	High (continuing)	
3.1	Oil & gas drilling						Noise pollution is a concern, but covered under 6.3
3.2	Mining & quarrying						Noise pollution is a concern, but covered under 6.3
3.3	Renewable energy	AB	Very High - High	Pervasive (71-100%)	Extreme - serious	High (continuing)	Collisions with wind turbines are a significant threat, killing many Hoary Bats. Turbines also kill aerial insects, reducing prey for Hoary Bats on migration routes. Wind energy developments are forecast to increase significantly.
4	Transportation & service corridors	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	
4.1	Roads & railroads	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Increased road density and development of roads can remove habitat. Bats also are occasionally struck by vehicles.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Restricted - small	Slight or 1-10% pop. decline	High (continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting	D	Low	Restricted - small	Slight or 1-10% pop. decline	High (continuing)	Habitat loss and direct mortality from tree felling. Loss of old forest is a concern but thinning of mature forest may be beneficial to Hoary Bats.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance						
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	
7.1	Fire & fire suppression	D	Low	Restricted - small	Slight or 1-10% pop. decline	High (continuing)	Similar impacts as for logging (loss of roosting trees and direct mortality). Increased size, severity, and frequency of forest fires are a result of global warming and particularly severe in boreal regions. Smoke from forest fires is included separately under 9.5.
7.2	Dams & water management/use						
7.3	Other ecosystem modifications	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Reduction in insect prey from various sources
8	Invasive & other problematic species & genes		Negligible	Small (1-10%)	Negligible or <1% pop. decline	High (continuing)	
8.1	Invasive non-native/alien species		Negligible	Small (1-10%)	Negligible or <1% pop. decline	High (continuing)	White-nose syndrome is not an issue for Hoary Bats. The issue identified here is predation by domestic cats and exotic burdock.
8.2	Problematic native species						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - slight	High (continuing)	Severity for roll-up raised to reflect additive effects

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.1	Household sewage & urban waste water	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Household pollutants may be a concern, especially at point sources such as sewage lagoons that may be used for foraging or drinking.
9.2	Industrial & military effluents	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Same as above in relation to industrial pollutants
9.3	Agricultural & forestry effluents	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Loss of insect prey due to pesticides used in forestry is scored in 7.3. Direct impacts difficult to quantify. Long-lived obligate aerial insectivores that migrate to southern areas (e.g., USA) where declines in aerial insects have been severe.
9.4	Garbage & solid waste						Microplastics may be a concern but scored in 9.1
9.5	Air-borne pollutants	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Mercury and smoke from forest fires are two main concerns. Bioaccumulation of other heavy metals and other pollutants from insect prey is a concern, given that Hoary Bats are long-lived.
9.6	Excess energy	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Noise. All industries combined that are noisy may reduce the effectiveness of echolocation and make habitat unusable for foraging (e.g., mining, oil and gas, logging).
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.1	Habitat shifting & alteration		Not Calculated (outside assessment timeframe)	Pervasive (71-100%)	Unknown	Low (long-term)	None of these climate change induced changes are likely to have negative impacts on Hoary Bats at the population level in the short term
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).

Appendix 2. Threat assessment for Eastern Red Bat in Canada.

Species or Ecosystem Scientific Name	*Lasiurus borealis*	**Element ID**		**English Name**	Eastern Red Bat
Version Date:	13-August-2022				
Version Author(s):	Kristiina Ovaska, Stephen Petersen, Erin Baerwald, Cory Olson, Elizabeth Gillis, Fanie Pelletier, Donald Sam, Thomas Jung, Lynne Burns, Lisa Wilkinson, Kristin Cline, Pierre-Andre Bernier, Adam Grottoli, Courtney Baldo, Dana Green, Jolene Laverty, Emma Pascoe				
References:	COSEWIC status report, draft				
Generation Time:	2-6 years (6 years used by call participants)				

Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	2	1
	C	Medium	1	1
	D	Low	4	5
Calculated Overall Threat Impact:			**Very High**	**High**
Assigned Overall Threat Impact:			**AB = Very High - High**	
Impact Adjustment Reasons:				
Overall Threat Comments			Threats are many and cumulative; however, the overall threat impact is largely driven by the threat of expanding wind energy development. The scope and severity of other potential threats (e.g., disease) are unknown and not estimated.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Moderate - slight	High (continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Slight or 1-10% pop. decline	High (continuing)	New residential and urban developments likely have a mixed effect on Eastern Red Bats, as loss of trees as roosting habitat will mean some significant areas are no longer suitable. On the other hand, planting trees to provide greener urban areas offsets the net loss of trees to a degree.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Moderate - slight	High (continuing)	Similar to above, but perhaps with less mitigation through planting or retention of trees. Emphasis may be more on loss of wetlands as foraging habitat.
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture	D	Low	Restricted - small	Moderate - slight	High (continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops	D	Low	Restricted - small	Moderate - slight	High (continuing)	Likely varies by region with increasing impact in the west, where conversion of land to agriculture increases, and likely negligible impacts in Ontario eastward, where old field conversion to forest provides increasingly more habitat. Loss of roost trees and wetlands (foraging habitat) is the main impact.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching		Negligible	Large (31-70%)	Negligible or <1% pop. decline	High (continuing)	Overgrazing of riparian areas. Entanglement on barbed wire is also a potential concern, and athough the scope is large the rare cases are likely fatal.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining	B	High	Pervasive - large	Serious or 31-70% pop. decline	High (continuing)	
3.1	Oil & gas drilling						Noise pollution is a concern, but covered under 6.3
3.2	Mining & quarrying						Noise pollution is a concern, but covered under 6.3
3.3	Renewable energy	B	High	Pervasive - large	Serious or 31-70% pop. decline	High (continuing)	Collisions with wind turbines are a significant threat, killing many Eastern Red Bats (but not as great an issue as for Hoary Bats). Wind energy developments are forecasted to increase significantly.
4	Transportation & service corridors	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	
4.1	Roads & railroads	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Increased road density and development of roads can remove habitat. Bats also are occasionally struck by vehicles.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Restricted - small	Slight or 1-10% pop. decline	High (continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting	D	Low	Restricted - small	Slight or 1-10% pop. decline	High (continuing)	Habitat loss and direct mortality from tree felling. Loss of old forest is not a concern and thinning mature forest may be beneficial to Eastern Red Bats, which use deciduous trees more than Hoary Bats or Silver-haired Bats.
5.4	Fishing & harvesting aquatic resources						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6	Human intrusions & disturbance						
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	
7.1	Fire & fire suppression	D	Low	Restricted - small	Slight or 1-10% pop. decline	High (continuing)	Similar impacts as that for logging (loss of roosting trees and direct mortality). Increased size, severity, and frequency of forest fires are a result of global warming and particularly severe in boreal regions; however, preference for deciduous forest means that Eastern Red Bats are likely less effected by forest fires. Smoke from forest fire is included seperately under 9.5.
7.2	Dams & water management/use						
7.3	Other ecosystem modifications	BC		Pervasive (71-100%)	Serious - moderate	High (continuing)	Reduction in insect prey from various sources
8	Invasive & other problematic species & genes	D	Low	Small (1-10%)	Slight or 1-10% pop. decline	High (continuing)	
8.1	Invasive non-native/alien species	D	Low	Small (1-10%)	Slight or 1-10% pop. decline	High (continuing)	White-nose syndrome is not an issue for Eastern Red Bats. The issue identified here is predation by domestic cats.
8.2	Problematic native species						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - slight	High (continuing)	Severity for roll-up raised to reflect additive effects
9.1	Household sewage & urban waste water	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Household pollutants may be a concern, especially at point sources such as sewage lagoons that may be used for foraging or drinking.
9.2	Industrial & military effluents	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Same as above in relation to industrial pollutants
9.3	Agricultural & forestry effluents	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Loss of insect prey due to pesticides used in forestry are scored in 7.3. Direct impacts difficult to quantify. Long-lived, obligate aerial insectivores that migrate to southern areas (e.g., USA) where declines in aerial insects have been severe.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.4	Garbage & solid waste						Microplastics may be a concern but scored in 9.1
9.5	Air-borne pollutants	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Mercury and smoke from forest fires are two main concerns. Bioaccumulation of other heavy metals and other pollutants from insect prey is a concern, given Eastern Red Bats are long-lived.
9.6	Excess energy	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Noise. All industries combined that are noisy may affect the effectiveness of echolocation and make habitat unusable for foraging (e.g., mining, oil and gas, logging, etc.).
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.1	Habitat shifting & alteration		Not Calculated (outside assessment timeframe)	Pervasive (71-100%)	Unknown	Low (long-term)	None of these climate change induced changes are likely to have negative impacts on Eastern Red Bats at the population level in the short term
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							

Appendix 3. Threat assessment of Silver-haired Bat in Canada.

THREATS ASSESSMENT WORKSHEET					
Species or Ecosystem Scientific Name	*Lasionycteris noctivagans*	Element ID		English Name	Silver-haired Bat
Version Date:	13-August-2021				
Version Author(s):	Kristiina Ovaska, Stephen Petersen, Erin Baerwald, Cory Olson, Elizabeth Gillis, Fanie Pelletier, Donald Sam, Thomas Jung, Lynne Burns, Lisa Wilkinson, Kristin Cline, Pierre-Andre Bernier, Adam Grottoli , Courtney Baldo, Dana Green, Jolene Laverty, Emma Pascoe				
References:	COSEWIC status report, draft				
Generation Time:	2-4 years (4 years used by call participants)				

Overall Threat Impact Calculation Help			Level 1 Threat Impact Counts	
	Threat Impact		high range	low range
	A	Very High	0	0
	B	High	2	1
	C	Medium	1	1
	D	Low	4	5
Calculated Overall Threat Impact:			Very High	High
Assigned Overall Threat Impact:			AB = Very High - High	
Impact Adjustment Reasons:				
Overall Threat Comments			Threats are many and cumulative; however, the overall threat impact is largely driven by the threat of expanding wind energy development. The scope and severity of other potential threats (e.g., disease) are unknown and not estimated.	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development		Negligible	Negligible (<1%)	Moderate - slight	High (continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Slight or 1-10% pop. decline	High (continuing)	New residential and urban developments likely have a mixed effect on Silver-haired Bats, as loss of trees as roosting habitat will mean some significant areas are no longer suitable. On the other hand, planting trees to provide greener urban areas offsets the net loss of trees to a degree.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Moderate - slight	High (continuing)	Similar to above, but perhaps with less mitigation by planting or retention of trees. Emphasis may be more on loss of wetlands as foraging habitat.
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture	D	Low	Restricted - small	Moderate - slight	High (continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops	D	Low	Restricted - small	Moderate - slight	High (continuing)	Likely varies by region with increasing impact in the west where conversion of land to agriculture increases, and likely negligable impacts in Ontario eastward where old field conversion to forest provides increasingly more habitat. Loss of roost trees and wetlands (foraging habitat) are the main impact.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching		Negligible	Large (31-70%)	Negligible or <1% pop. decline	High (continuing)	Overgrazing of riparian areas. Entanglment on barbed wire is also a potential concern, and athough the scope is large and occurrences are rare but likely fatal. No reports of these bats getting caught in barbed wire but reports exist for other migratory bats
2.4	Marine & freshwater aquaculture						
3	Energy production & mining	B	High	Large (31-70%)	Serious or 31-70% pop. decline	High (continuing)	
3.1	Oil & gas drilling						Noise pollution is a concern, but covered under 6.3
3.2	Mining & quarrying			Unknown	Extreme or 71-100% pop. decline	High (continuing)	Noise pollution is a concern, but covered under 6.3
3.3	Renewable energy	B	High	Large (31-70%)	Serious or 31-70% pop. decline	High (continuing)	Collisions with wind turbines are a significant threat, killing many Silver-haired Bats (but not as great an issue as for Hoary Bats or Eastern Red Bats). Wind energy developments are forecast to increase significantly.
4	Transportation & service corridors	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	
4.1	Roads & railroads	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Increased road density and development of roads can remove habitat. Bats also are occasionally struck by vehicles.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Restricted (11-30%)	Moderate - slight	High (continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Moderate - slight	High (continuing)	Habitat loss and direct mortality from tree felling. Loss of old forest is a concern.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Unknown	Unknown	Serious - slight	High (continuing)	
6.1	Recreational activities			Unknown	Serious - slight	High (continuing)	Caving can disturb hibernating or roosting bats
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	
7.1	Fire & fire suppression	D	Low	Large - restricted	Slight or 1-10% pop. decline	High (continuing)	Similar impacts as for logging (loss of roosting trees and direct mortality). Increased size, severity, and frequency of forest fires are a result of global warming and particularly severe in boreal regions. Smoke from forest fires is included separately under 9.5.
7.2	Dams & water management/use						
7.3	Other ecosystem modifications	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Reduction in insect prey from various sources
8	Invasive & other problematic species & genes	D	Low	Small (1-10%)	Moderate - slight	High (continuing)	
8.1	Invasive non-native/alien species	D	Low	Small (1-10%)	Moderate - slight	High (continuing)	White-nose syndrome may be an issue for Silver-haired Bats but the risk is unclear. Predation by domestic cats is a potential issue.
8.2	Problematic native species						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - slight	High (continuing)	Severity for roll-up raised to reflect additive effects
9.1	Household sewage & urban waste water	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Household pollutants may be a concern, especially at point sources such as sewage lagoons that may be used for foraging or drinking.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.2	Industrial & military effluents	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Same as above in relation to industrial pollutants
9.3	Agricultural & forestry effluents	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Loss of insect prey due to pesticides used in forestry is scored in 7.3. Direct impacts difficult to quantify. Long-lived obligate aerial insectivores that migrate to southern areas (e.g., USA) where declines in aerial insects have been severe.
9.4	Garbage & solid waste						Microplastics may be a concern but scored in 9.1
9.5	Air-borne pollutants	D	Low	Pervasive (71-100%)	Slight or 1-10% pop. decline	High (continuing)	Mercury and smoke from forest fires are two main concerns. Bioaccumulation of other heavy metals and other pollutants from insect prey is a concern, given Silver-haired bats are long-lived.
9.6	Excess energy	D	Low	Pervasive - large	Slight or 1-10% pop. decline	High (continuing)	Noise. All industries combined that are noisy may reduce the effectiveness of echolocation and make habitat unusable for foraging (e.g., mining, oil and gas, logging).
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.1	Habitat shifting & alteration		Not Calculated (outside assessment timeframe)	Pervasive (71-100%)	Unknown	Low (long-term)	None of these climate change induced changes are likely to have negative impacts on Silver-haired Bats at the population level in the short term
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).