COSEWIC
Assessment and Status Report

on the

Bicknell's Thrush
Catharus bicknelli

in Canada

THREATENED
2022

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:

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Previous report(s):

COSEWIC. 2009. COSEWIC assessment and status report on the Bicknell's Thrush *Catharus bicknelli* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 44 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

COSEWIC. 1999. COSEWIC assessment and status report on the Bicknell's Thrush *Catharus bicknelli* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 43 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Nixon E. 1999. COSEWIC status report on the Bicknell's Thrush *Catharus bicknelli* in Canada, *in* COSEWIC assessment and status report on the Bicknell's thrush *Catharus bicknelli* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-43 pp.

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Bicknell's Thrush — Photo credit: Éric Deschamps

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COSEWIC
Assessment Summary

Assessment Summary – December 2022

Common name
Bicknell's Thrush

Scientific name
Catharus bicknelli

Status
Threatened

Reason for designation
This songbird is now largely restricted to breeding in regenerating high-elevation forests in parts of southern Quebec, New Brunswick, Nova Scotia, and adjacent mountains of northeastern United States. Information from several survey sources confirms that breeding numbers continue to decline markedly, with the recent loss from coastal breeding sites and former strongholds on Cape Breton Island. Declines are expected to continue into the future in response to a range of threats. These include loss of forested wintering habitat on Caribbean islands, impacts of introduced Moose on Cape Breton and non-native rats on wintering grounds, habitat alteration from precommercial thinning and conversion of fir forests to spruce plantations, and impacts of climate change on forest composition.

Occurrence
Quebec, New Brunswick, Nova Scotia

Status history
Designated Special Concern in April 1999. Status re-examined and designated Threatened in November 2009. Status re-examined and confirmed in December 2022.

COSEWIC
Executive Summary

Bicknell's Thrush
Catharus bicknelli

Wildlife Species Description and Significance

Bicknell's Thrush (*Catharus bicknelli*) is a medium-sized thrush with a limited breeding distribution in northeastern North America. It is of high conservation concern due to its limited range, specific habitat requirements on breeding and wintering grounds, the naturally fragmented nature of its habitat, and the many threats it faces. It was first recognized as a full species in 1995, based on morphological, vocal, and genetic distinctiveness, and its disjunct geographic distribution in relation to the Gray-cheeked Thrush.

Distribution

Bicknell's Thrush breeds in parts of Quebec, New Brunswick, and Nova Scotia in eastern Canada and New York, Vermont, New Hampshire, and Maine in the northeastern United States. It winters only on islands in the Caribbean Sea, including Cuba, Jamaica, Puerto Rico, Haiti, and the Dominican Republic.

Habitat

The breeding range of Bicknell's Thrush is restricted to high elevations and areas subject to natural environmental stresses, such as high winds, winter ice accumulation, and cool sea breezes. It nests from elevations above 1150 m in the Appalachian Mountains to near sea level on scattered coastal sites. Bicknell's Thrush usually breeds in stands dominated by Balsam Fir (with subdominant White Birch and Red Spruce), including clear-cut harvest blocks, but avoids recently-thinned stands. Its strong association with Balsam Fir limits habitat availability on high plateaus. Bicknell's Thrush winters primarily in mesic to wet broadleaf montane forests, with more than half of its inferred wintering habitat in the Dominican Republic. Worst-case climate change scenarios predict that breeding habitat may decline by more than half by about 2100.

Biology

Bicknell's Thrush is unusual among thrushes in that it engages in dynamic female-defense polygynandry mating associations, in which most females are assisted by up to four males in provisioning at the nest, with some males feeding two broods simultaneously. The number of provisioning males is higher when prey abundance is low. Females regularly call, sing, and exclude conspecific females from their home ranges, whereas male home ranges overlap extensively. Both sexes defend small territories in dense vegetation on the wintering grounds, where there is evidence of sex-based habitat partitioning, with males tending to occur at higher elevations.

Population Size and Trends

The Canadian population of Bicknell's Thrush is estimated to be about 21,300–91,000 mature individuals, based on a revised population estimate for Quebec and the results of the second breeding bird atlases of Quebec and the Maritime provinces, and factoring in evidence of recent population declines.

Very limited Breeding Bird Survey (BBS) results suggest that the number of Bicknell's Thrush breeding in Canada declined by about -53.7% (95% CI: -90.2, -10.3) over 10 years. Longer-term trends (1970-2019) are also negative, equivalent to a cumulative decline of about -87.2% (95% CI: -98.8, -32.7) over 49 years. However, as relatively few BBS routes are located in Bicknell's Thrush habitat, the 10-year trend estimate has broad uncertainty and low statistical reliability. It may therefore be better estimated by interpolation that is based on the long-term annual rate of decline, which yields an estimated decline of about -34.2% (95% CI: -59.6 to -7.8) over 10 years. The recent disappearance of Bicknell's Thrush from some coastal sites in Quebec, southwestern Nova Scotia, and the Bay of Fundy, and recent loss of the species from former strongholds on Cape Breton Island, shows that breeding range continues to contract.

Threats and Limiting Factors

Bicknell's Thrush is particularly vulnerable to anthropogenic threats, owing to its high degree of habitat specialization, its relatively low reproductive rate, and sex-specific habitat partitioning in winter, which may make females more vulnerable to human disturbance. Most of the important threats affect habitat, including alteration of breeding habitat quality by precommercial thinning and conversion of fir forests to spruce plantations, and loss of wintering habitat on Caribbean islands due to local forest clearing for agriculture. Introduced Moose have slowed forest habitat regeneration on Cape Breton Island. Other threats include predation by non-native rats on wintering grounds and degradation and habitat loss through wind farm construction on high-elevation breeding habitat. Many of these impacts may be compounded by the ongoing effects of climate change on forest composition.

Protection, Status, and Ranks

Bicknell's Thrush was listed as Threatened in Canada under the *Species at Risk Act* in 2012. The species and its nests are protected in Canada under the *Migratory Birds Convention Act* (1994). It is considered Vulnerable in Quebec, Threatened in New Brunswick, and Endangered in Nova Scotia. Bicknell's Thrush is considered Apparently Secure by NatureServe (G4), and it is listed as Vulnerable on the IUCN Red List. It is identified by the US Fish and Wildlife Service as a Bird Species of National Concern, and it is on the Red Watch List of Partners in Flight as a Species of Conservation Concern. Four large protected areas, including Cape Breton Highlands National Park, Parc national de la Gaspésie, Parc national des Monts-Valins, and Parc national des Hautes-Gorges-de-la-Rivière-Malbaie, appear to host substantial areas of good quality breeding habitat for Bicknell's Thrush.

TECHNICAL SUMMARY

Catharus bicknelli

Bicknell's Thrush

Grive de Bicknell

Range of occurrence in Canada (province/territory/ocean): Quebec, New Brunswick, Nova Scotia

Demographic Information

Generation time (usually average age of parents in the population)	2.32 years	Bird *et al.* (2020)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes	Inferred decline, based on BBS, Mountain Birdwatch, and ÉPOQ and eBird trend estimates
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].	(a) -31.9% (95% CI: -68.7%, +5.0%) over 5 years, or: (b) -18.9% (95% CI: -36.5, -4.0) over 5 years	Estimated decline from 2014–2019, derived from limited BBS results: (a) based on BBS data over 5 years; (b) inferred by applying long-term BBS rate of decline to the 5-year period
[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].	(a) -53.7% (95% CI: -90.2, -10.3) over 10 years, or: (b) -34.2% (95% CI: -59.6, -7.8) over 10 years	Estimated decline from 2009–2019, derived from limited BBS results: (a) based on BBS data over 10 years; (b) inferred by applying long-term BBS rate of decline to the 10-year period (see Fluctuations and Trends).
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 10 years.	Projected continuing decline at similar rates	Inferred from anticipated effects of threats with High-Medium impact
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over 10 years, including both the past and the future.	Projected continuing decline at similar rates	Recent decline projected to continue into future at similar rates, inferred from anticipated effects of threats with High-Medium impact
Are the causes of the decline clearly understood?	Yes, for most causes	Primarily loss and degradation of forested breeding and wintering habitat
Have the causes of the decline ceased?	No	Forest management on the breeding grounds and habitat degradation on wintering grounds are continuing
Are the causes of the decline clearly reversible?	No, many are not reversible over the short term	Direct human-caused habitat impacts may be reversible in the longer term, but those related to climate change may not be
Are there extreme fluctuations in number of mature individuals?	No	

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	311,985–427,065 km^2	Calculated using a minimum convex polygon around known (minimum) and potential (maximum) breeding areas
Index of area of occupancy (IAO), reported as 2x2 km grid value.	968–54,208 km^2	Range is based on known (minimum) and potential (maximum) breeding sites; actual value may be closer to maximum estimate
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)	Unknown, but likely >10	
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Yes	Observed and projected decline, with reduction documented by breeding bird atlases (Whittam 2015; Aubry and Shaffer 2019)
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Yes	Observed and projected decline, with reduction documented by breeding bird atlases in the Maritime provinces (Whittam 2015).
Is there an [observed, inferred, or projected] continuing decline in number of subpopulations?	No	Not applicable; no subpopulations
Is there an [observed, inferred, or projected] continuing decline in number of "locations"*?	No	Based on threats from forestry activities, which affect many relatively small areas differently, and shifts across the landscape over time
Is there an [observed, inferred, or projected] continuing decline in [area, extent, and/or quality of] habitat?	Yes, inferred and observed continuing decline in area and quality of breeding and wintering habitat	Inferred from climate change modelling and observed habitat alterations associated with forest management and clearing for agriculture
Are there extreme fluctuations in number of subpopulations?	No	Not applicable
Are there extreme fluctuations in number of "locations"*?	No	
Are there extreme fluctuations in extent of occurrence?	No	
Are there extreme fluctuations in index of area of occupancy?	No	

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

Number of Mature Individuals (in each subpopulation)

Subpopulations (no subpopulations; provincial estimates provided here)	N Mature Individuals	Notes on individual estimates
Quebec	14,000–59,700	Based on revised estimate (Aubry pers. comm. 2021)
New Brunswick	5,100–21,800	Based on revised estimate for Quebec, and proportion of squares occupied in recent breeding bird atlas (Stewart *et al.* 2015)
Nova Scotia	2,200–9,500	Based on revised estimate for Quebec, and proportion of squares occupied in recent breeding bird atlas (Stewart *et al.* 2015)
Total	21,300–91,000	Based on revised estimate for Quebec and the relative number of occupied atlas squares, and accounting for recent rates of decline shown by the BBS

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]?	Unknown	Analysis not conducted

Threats and Limiting Factors

Was a threats calculator completed for this species?	Yes, on 7 September 2021	Overall threat impact: High-Medium

The following contributing threats were identified, listed in decreasing order of impact, and excluding those of negligible impact (see Appendix 1):

IUCN 5. Biological resource use (Medium-Low threat impact)
IUCN 8. Invasive and other problematic species and genes (Medium-Low threat impact)
IUCN 1. Residential and commercial development (Low threat impact)
IUCN 2. Agriculture and aquaculture (Low threat impact)
IUCN 3. Energy production and mining (Low threat impact)
IUCN 7. Natural system modifications (Unknown threat impact)
IUCN 9. Pollution (Unknown threat impact)
IUCN 11. Climate change and severe weather (Unknown threat impact)

What additional limiting factors are relevant?
Specialized ecological requirements on breeding and wintering grounds, sex-specific habitat segregation on the wintering grounds, relatively low productivity, being single-brooded with a relatively small clutch size, and a male-biased sex ratio. Sex-specific habitat use on the wintering grounds may place females at higher risk of habitat loss.

Rescue Effect (natural immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada	Generally declining	Most potential source populations in northeastern US are declining but may be stable to slightly increasing in Vermont (Hill 2020).
Is immigration known or possible?	Possible	Yes, interpopulation movement is likely, based on evidence of extensive natal dispersal (Studds *et al.* 2012).
Would immigrants be adapted to survive in Canada?	Yes	Conditions in Canada are similar to those in US source areas.
Is there sufficient habitat for immigrants in Canada?	Yes	Areas of potential breeding habitat are apparently available in Quebec (Aubry *et al.* 2018, Aubry pers. comm. 2020).
Are conditions deteriorating in Canada?[+]	Yes	Ongoing decline in extent and quality of breeding habitat due to forestry operations, Spruce Budworm outbreak, and climate change.
Are conditions for the source (i.e., outside) population deteriorating?[+]	Yes	Habitat quality is decreasing in northeastern US, with dieback of high-elevation conifer stands and predicted effects of climate change.
Is the Canadian population considered to be a sink?[+]	Unknown	
Is rescue from outside populations likely?	No, unlikely	Most source populations in northeastern US are declining.

Occurrence Data Sensitivity

Are occurrence data of this species sensitive?	No

Status History

COSEWIC: Designated Special Concern in April 1999. Status re-examined and designated Threatened in November 2009. Status re-examined and confirmed in December 2022.

Status and Reasons for Designation

NOTE: Recommended status is changed to Current status after a Wildlife Species Assessment Meeting when the report is finalized.	
Current Status: Threatened	**Alpha-numeric codes:** A2bce+3bce+4bce

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

Reasons for designation (2022):	
Reasons for designation (2022): This songbird is now largely restricted to breeding in regenerating high-elevation forests in parts of southern Quebec, New Brunswick, Nova Scotia, and adjacent mountains of northeastern United States. Information from several survey sources confirms that breeding numbers continue to decline markedly, with the recent loss from coastal breeding sites and former strongholds on Cape Breton Island. Declines are expected to continue into the future in response to a range of threats. These include loss of forested wintering habitat on Caribbean islands, impacts of introduced Moose on Cape Breton and non-native rats on wintering grounds, habitat alteration from precommercial thinning and conversion of fir forests to spruce plantations, and impacts of climate change on forest composition.	
Reason for change of status	Not applicable

Applicability of Criteria

A: Decline in total number of mature individuals Meets Threatened, A2bce+3bce+4bce, based on estimates of declines in the number of mature individuals exceeding 30% over the past 10 years. These estimates of declines come from limited Breeding Bird Survey data, are supported by results of species-specific surveys, and are expected to continue into the future at similar rates over the next 10 years, together with declines in IAO, EOO, and quality of habitat, with the effects of introduced mammals contributing to the decline.
B: Small distribution range and decline or fluctuation Not applicable. Estimated EOO exceeds thresholds; although the minimum estimate of IAO is <2000 km², with a continuing inferred decline in EOO and IAO, area, and quality of habitat and an observed decline in number of mature individuals, the population occurs at more than 10 locations and is not severely fragmented or subject to extreme fluctuations.
C: Small and declining number of mature individuals Not applicable. Minimum population estimate of 21,300 mature individuals is higher than thresholds.
D: Very small or restricted population Not applicable. Minimum population estimate of 21,300 mature individuals and IAO are higher than thresholds.
E: Quantitative analysis Not applicable. Analysis not done.

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
(2022)

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.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name:	*Catharus bicknelli*
English name:	Bicknell's Thrush
French name:	Grive de Bicknell
Classification:	Class: Aves
Order:	Passeriformes
Family:	Turdidae

Relatively small and slender compared to its congeners, Bicknell's Thrush is a sister species of Gray-cheeked Thrush (*C. minimus*), from which it was only distinguished in 1995 (A.O.U. 1995). It was recognized as a full species on the basis of morphometric, acoustic, behavioural, genetic, and distributional evidence compiled by Ouellet (1993). One case of hybridization with Veery (*C. fuscescens*) has been inferred from vocalizations and genetic data (Martinsen *et al.* 2018), and a putative hybrid with Gray-cheeked Thrush was reported by Fitzgerald *et al*. (2017) based on genetic data.

Morphological Description

Bicknell's Thrush is a small *Catharus* thrush species in which sexes are similar, except for the fact that females have a slightly shorter wing chord (Frey *et al.* 2008). Males average 28.2 g in mass and females average 32.0 g (Townsend *et al.* 2020). Mean wing chord is 92.9 mm for males and 87.8 mm for females (Townsend *et al.* 2020). Bicknell's Thrush has olive-brown to brownish upperparts (head, nape, and back) that contrast slightly with the chestnut-tinged tail (cover picture; Townsend *et al.* 2020). The breast is pale with a buffy wash, with greyish flanks and dusky spots that become diffuse toward the sides and the lower breast. It has grey cheeks, a faint grey eye-ring, a bicoloured bill, and pink legs.

Although differences in plumage colouration are used to distinguish between Bicknell's and Gray-cheeked Thrush (e.g., Todd 1963), reliable identification in the field is difficult (Townsend *et al.* 2020). The species is best distinguished by its song, which is high-pitched and flute-like, usually made up of four phrases and rising slightly at the end. Wing length can be used to distinguish most individuals in the hand as the Gray-cheeked Thrush generally has a wing chord of >95 mm, whereas 85% of Bicknell's Thrush have a wing chord of <95 mm (Ouellet 1993). However, wing length measurements of young female Gray-cheeked and adult male Bicknell's Thrush may overlap (Townsend *et al.* 2020).

Population Spatial Structure and Variability

No subspecies of Bicknell's Thrush have been described (Townsend *et al.* 2020). Todd (1963) suggested that birds from New York and New England were tawnier brown than those in the Maritime provinces and southeastern Quebec, which the author described as a colder olive-brown. It is unclear whether this possible north-south trend in plumage colour represents a true cline or whether these colour types are intermixed throughout the species' range (Townsend *et al.* 2020).

Designatable Units

Bicknell's Thrush was considered as one Designatable Unit (DU) in Canada in previous status assessments (e.g., COSEWIC 2009). With no subspecies (Townsend *et al.* 2020), an extensive mixing of breeding populations on the wintering grounds suggested by deuterium ratios (Hobson *et al.* 2001), and no evidence for discrete genetic or morphological differences of evolutionary significance among Bicknell's Thrush within Canada, the species is again considered here as one Designatable Unit.

Special Significance

Bicknell's Thrush is considered by McFarland *et al.* (2018) to be one of the species at highest risk of extinction among Nearctic-Neotropical migrant songbirds due to its restricted range and habitat requirements, unusual breeding structure, and threats related to declining habitat availability. Overall Canadian conservation responsibility for Bicknell's Thrush is high. No publicly available Aboriginal Traditional Knowledge was identified for Bicknell's Thrush. However, this species is part of Canadian ecosystems that are important to Indigenous people who recognize the interconnectedness of all species within these ecosystems.

DISTRIBUTION

Global Range

Bicknell's Thrush is a North American endemic species, breeding in the northeastern part of the continent and wintering in the Caribbean. It breeds in southern Quebec, northern New Brunswick, and northern Nova Scotia (Cape Breton Island) in eastern Canada, and northern portions of New York, Vermont, New Hampshire, and Maine in the northeastern United States (Figures 1, 2). It winters only in the Greater Antilles in the Caribbean Sea, including Cuba, Jamaica, Puerto Rico, Haiti, and the Dominican Republic (Figures 1, 3).

Most fall migrating Bicknell's Thrush move south along the Atlantic coast of the United States to Virginia (Bégin-Marchand *et al*. 2020). They then depart from the southeastern United States on an overwater flight to the Greater Antilles. Northbound spring migrants appear to follow a coastal trajectory from Florida to Virginia, with twice as many birds reported from this area in spring as in fall (Townsend *et al.* 2020).

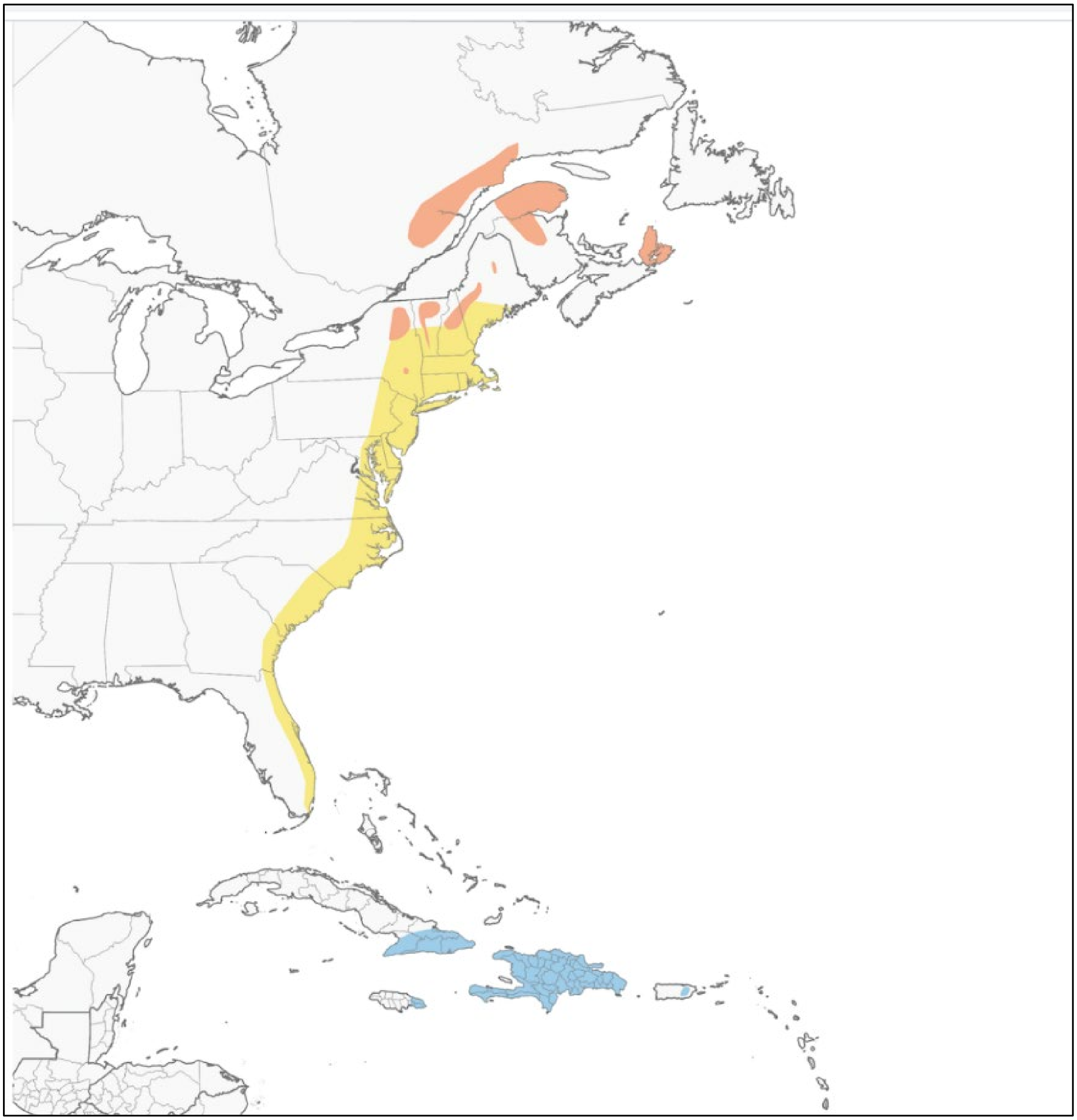

Figure 1. Global breeding, wintering, and migrating range of Bicknell's Thrush (from Townsend *et al.* 2020). Breeding range is shown in salmon, wintering range in blue, and main migratory pathways in yellow.

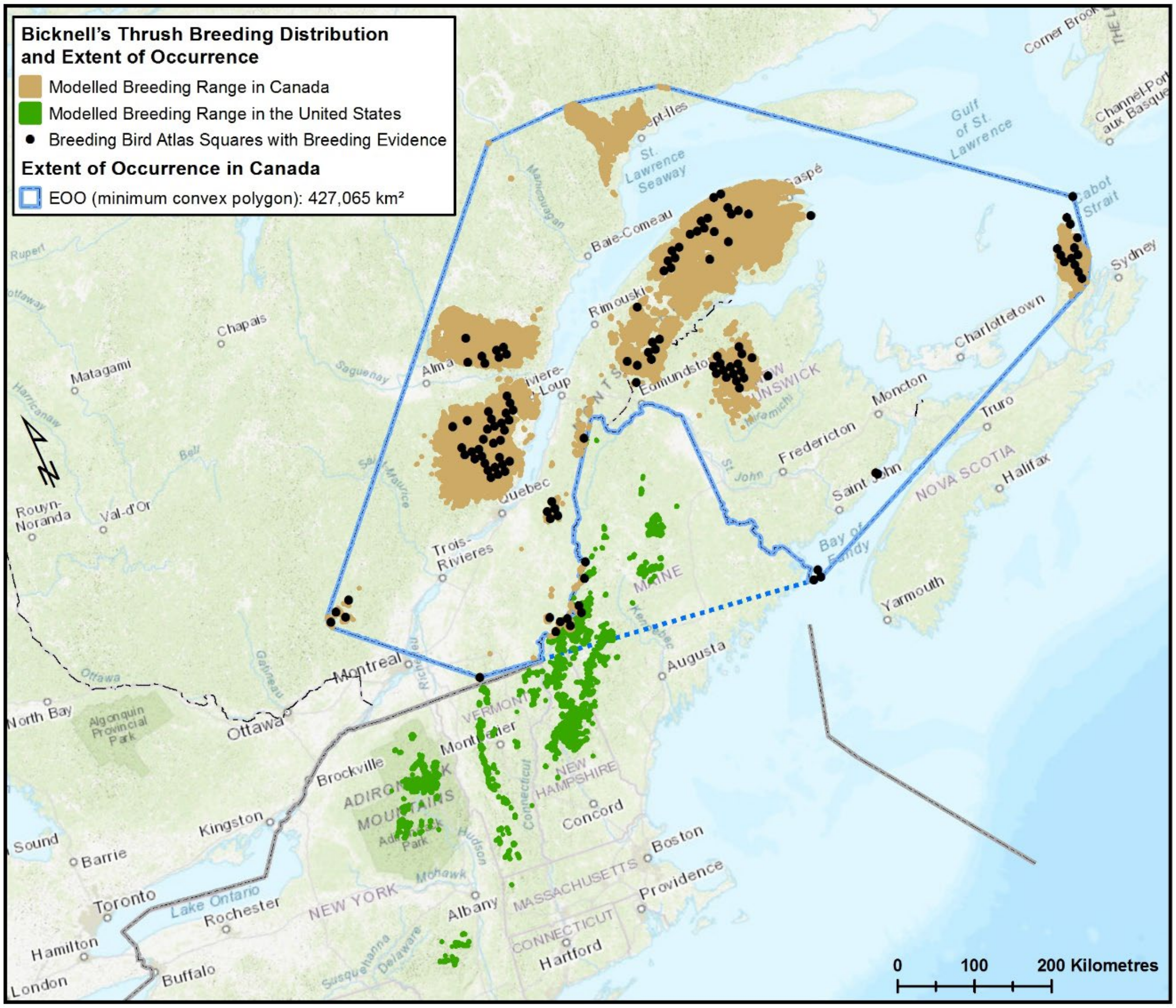

Figure 2. Modelled breeding range of Bicknell's Thrush in northeastern North America (from ECCC 2020). Black dots indicate 10 x 10 km^2 atlas squares in which Bicknell's Thrush breeding evidence was reported in recent breeding bird atlases of the Maritime provinces (Stewart *et al*. 2015) and Quebec (Robert *et al*. 2019). The maximum estimated extent of occurrence in Canada is shown within a minimum convex polygon around the modelled breeding range (courtesy of S. Allen, COSEWIC secretariat).

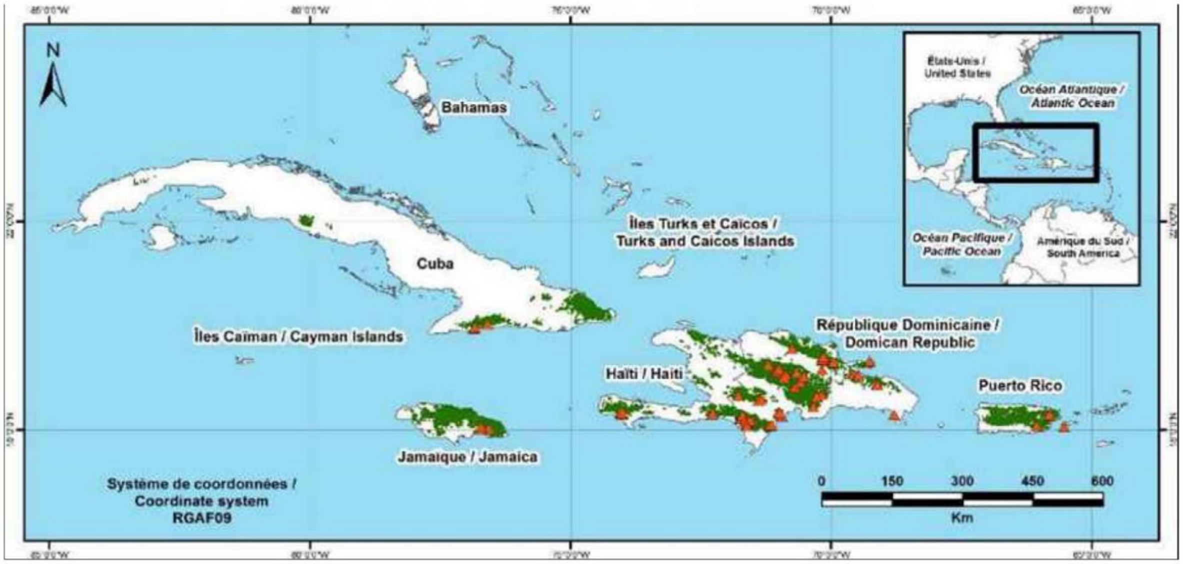

Figure 3. Modelled wintering range of Bicknell's Thrush on islands of the Greater Antilles in the Caribbean Sea (from ECCC 2020). Red triangles indicate sites known to be occupied (McFarland *et al.* 2013).

Canadian Range

According to model predictions, Canada is thought to host about 95% of the breeding habitat currently available for Bicknell's Thrush (ECCC 2020). In Quebec, Bicknell's Thrush breeds in dense fir-dominated stands at high elevations in the Appalachian Mountains, from Mont Sutton to the Gaspé Peninsula. North of the St. Lawrence River, Bicknell's Thrush has been reported from Mont Tremblant to the high plateau northwest of Sept-Îles. The breeding range is naturally fragmented by lowland areas and breaks in the occurrence of Balsam Fir (*Abies balsamea*), with large gaps between Appalachian peaks, and between Mont Tremblant and the Laurentian Highlands. There is also a large distribution gap between the Monts Valin region, north of the Saguenay River, and the Sept-Îles/Port-Cartier plateau. Bicknell's Thrush has not been reported during the breeding season in the Magdalen Islands in the Gulf of St. Lawrence since 1989. It has also disappeared from some coastal sites that were occupied during the first Quebec breeding bird atlas (Figure 4).

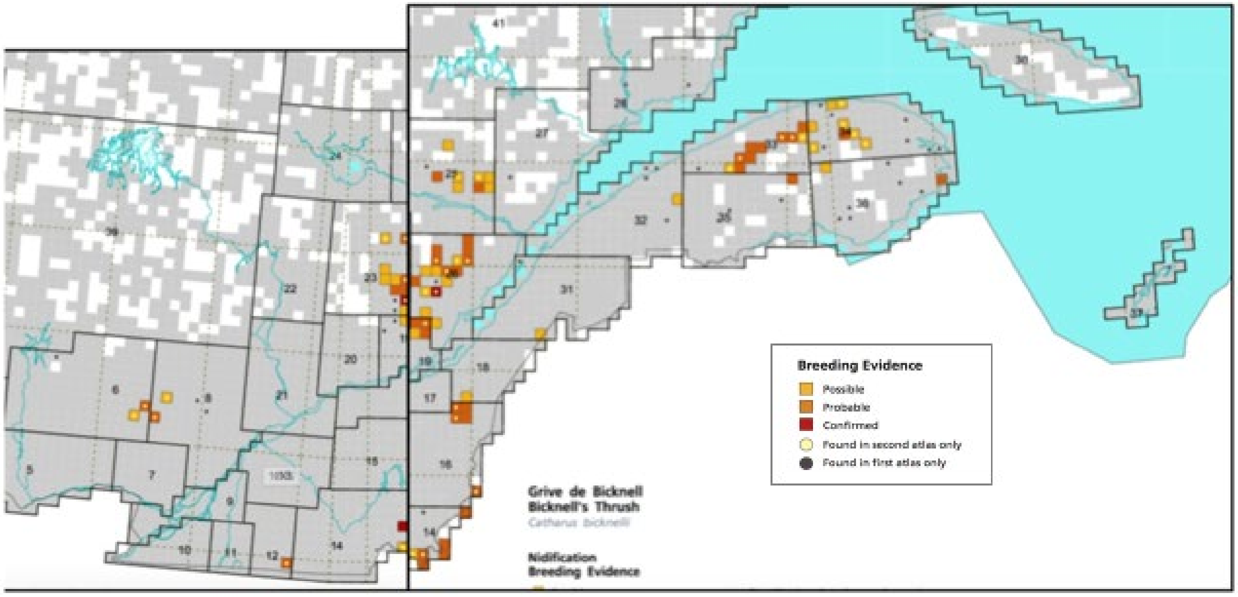

Figure 4. Bicknell's Thrush breeding distribution in southern Quebec during 2010–2014, from the Quebec Breeding Bird Atlas (Robert *et al.* 2019). Black dots (n = 36) depict 10 x 10 km squares in which Bicknell's Thrush was recorded during the first atlas (1984–1989) but not the second, and yellow dots (n = 33) depict squares in which it was recorded during the second atlas but not the first.

In New Brunswick, Bicknell's Thrush mainly breeds in the Highlands ecoregion, with scattered breeding individuals in the Northern Uplands ecoregion. The most recent summer sighting along the Bay of Fundy coast was of a singing individual at Fundy National Park in July 2009 (eBird 2021). Breeding habitat in Nova Scotia is concentrated in the Cape Breton Highlands, with scattered sightings on St. Paul Island (none since 2010) and Scatarie Island (automated recording units—ARUs—deployed in 2018 and 2019 recorded one "probable" detection in 2019; L. Achenbach, unpubl. data). Bicknell's Thrush has not been reported during the breeding season from coastal sites in southwestern Nova Scotia (Cape Forchu, Seal, and Bon Portage Islands) since 1935, and the last report from West Advocate in the Bay of Fundy was in 1988 (eBird 2021). It has disappeared from other sites on the Bay of Fundy coast in Nova Scotia and New Brunswick that were occupied during the first Maritimes breeding bird atlas (1986–1990; Figure 5).

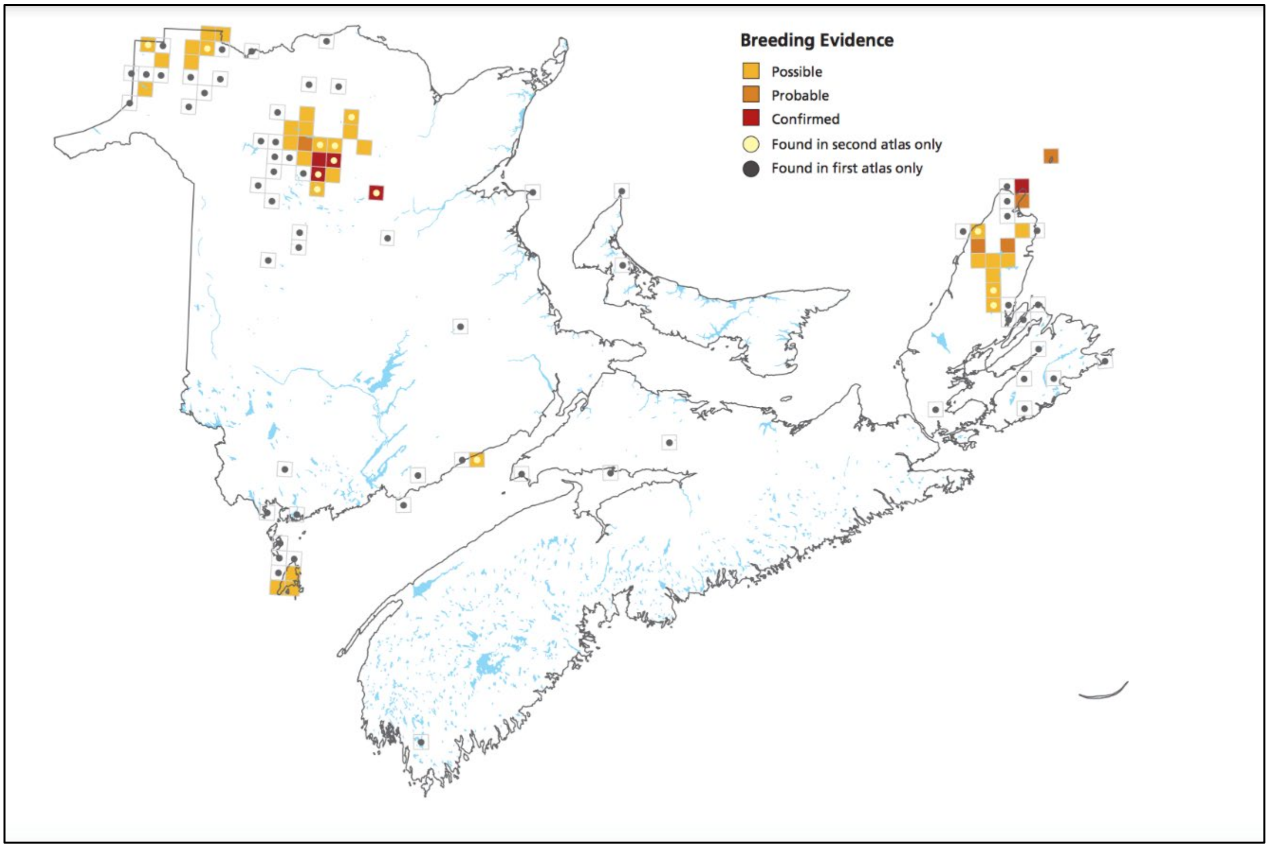

Figure 5. Bicknell's Thrush breeding distribution in the Maritime provinces (New Brunswick, Prince Edward Island, and Nova Scotia) during 2006–2010 from the Second Atlas of the Breeding Birds of the Maritime provinces (Stewart *et al*. 2015). Black dots (n = 60) depict 10 x 10 km squares in which Bicknell's Thrush was recorded during the first atlas (1986-1990) but not the second. Yellow dots depict squares (n = 13) where it was recorded during the second atlas but not the first.

Extent of Occurrence and Area of Occupancy

The current extent of occurrence (EOO) for Bicknell's Thrush is estimated as 311,985–427,065 km^2, calculated as a minimum convex polygon around current known breeding areas in Canada (Figure 2). The minimum value is based on a polygon drawn around those 10 km x 10 km squares with breeding evidence in the latest Quebec (Robert *et al.* 2019) and Maritimes (Stewart *et al.* 2015) breeding bird atlases. The maximum value is based on a polygon drawn around areas modelled as suitable breeding habitat in the Bicknell's Thrush recovery strategy (ECCC 2020). The actual EOO value is likely closer to the minimum estimate, which is based on observations rather than the habitat-based maximum as not all apparently suitable habitat is occupied.

Because the previous EOO estimate of 297,000 km^2 (COSEWIC 2009) was calculated using different methods and included birds breeding in the United States, these estimates cannot be directly compared. However, EOO has likely declined slightly over that period, with losses documented in several areas by breeding bird atlases (Whittam 2015; Aubry and Shaffer 2019), such as in southern Cape Breton Island (Figure 5).

The index of area of occupancy (IAO) for Bicknell's Thrush in Canada was obtained by overlaying a 2 x 2 km grid over possible breeding sites. A minimum IAO estimate of 484 km^2 can be determined by counting a single 2 x 2 km square for each occupied 10 x 10 km square in the most recent Quebec (Robert *et al.* 2019) and Maritimes (Stewart *et al.* 2015) breeding bird atlases. This approach underestimates the IAO as each occupied atlas square likely contains more than one occupied 2 x 2 km square, given that Bicknell's Thrush tend to aggregate in suitable habitat and not all squares with potential habitat were surveyed. The minimum estimate for the Canadian population of 21,300 mature individuals represents a density of about 44 individuals/km^2 (0.44/ha), approximately twice the densities estimated by Aubry in several regions of Quebec (Table 1). To account for this likely underestimation, the minimum estimate of IAO was doubled to 968 km^2. The maximum IAO estimate of 54,208 km^2 was obtained by overlaying the 2 x 2 km grid on the entire modelled habitat area (ECCC 2020; Figure 2). The actual IAO value may be close to the mid-range of the estimate as the maximum of 54,208 km^2 is based on the availability of suitable habitat, much of which is apparently unoccupied.

Table 1. Bicknell's Thrush density estimates (mature individuals/ha) derived from point count surveys conducted in Quebec, New Brunswick, and Nova Scotia.

Province	Site/region	Density (n)[1]		Reference
		<800 m above sea level	>800 m above sea level	
Quebec	Mégantic/Gosford	--[2]	0.16 (57)–0.50 (131)	Aubry (unpubl. data, 2003, 2008)
	Appalaches sud	0.05 (60)	0.16[3]	Aubry (unpubl. data, 2013)
	Massif du Sud	0.07 (111)–0.16 (26)	0.15 (35)–0.26 (39)	Aubry (unpubl. data, 2008, 2010, 2011)
	Rimouski	0 (60)	--[2]	Aubry (unpubl. data, 2013)
	Gaspésie	0.01 (379)–0.11 (40)	0.16 (10)–0.22 (16)	Aubry (unpubl. data, 2001, 2005)
	Mont Tremblant	0.002[4]	0.002[4]	eBird
	Plateau Laurentien	0.03[5]	0.02 (46)–0.13 (37)	Aubry (unpubl. data, 2013, 2014)
	Monts Valin	0.03 (208)–0.08 (92)	0.06 (104)–0.29 (20)	Aubry (unpubl. data, 2012, 2013)
	Sept-Îles/Port-Cartier	0.002 (401)	--[2]	Aubry (unpubl. data, 2006)
	Massif du Sud	0.14 (210)		Aubry *et al.* (2016)
	Mont Gosford	0.22 (129)–0.50 (129)		Aubry *et al.* (2016)
	Mont Sutton	--		eBird
New Brunswick	New Brunswick Highlands	0.16		Nixon *et al.* (2001)
	New Brunswick Highlands[6]	0.04–0.08		Kouwenberg (2020)

Province	Site/region	Density (n)[1]		Reference
		<800 m above sea level	>800 m above sea level	
	New Brunswick Highlands[7]	0.06–0.11		Kouwenberg (2020)
Nova Scotia	Cape Breton Highlands and Scatarie Island[6]	0.04–0.10		Kouwenberg (2020)
	Cape Breton Highlands and Scatarie Island[7]	0.01		Kouwenberg (2020)

[1]Number of distinct mature individuals/ha, based on detections within a 100 m radius. Calling and singing individuals were weighted equally. n = number of point count stations (Y. Aubry unpubl. data). Density estimates from other references listed are presumed to be derived using similar procedures.

[2]No Balsam Fir-dominated potential Bicknell's Thrush habitat available.

[3]No point count data at that elevation; extrapolation using Mégantic/Gosford density >800 m.

[4]Extrapolation using Sept-Îles/Port-Cartier density.

[5]Extrapolation using Monts Valin density <800 m.

[6]2012–2015

[7]2016–2019

IAO was estimated at 48,850 km^2 in the previous status assessment (COSEWIC 2009), based on a breeding habitat predictive model, and the same estimate was cited in the Bicknell's Thrush recovery strategy (ECCC 2020). This value cannot be compared directly with the current estimate of IAO as different methods were used to calculate them. However, the actual IAO has likely declined in the Maritime provinces, as suggested by the large number of atlas squares where the species was detected during the first atlas but not the second one (Figure 5), despite increased search effort (Whittam 2015). In Quebec, a more intensive search effort resulted in an increase of 21 occupied atlas squares between the first and second atlas, but occupied area is thought to have decreased in much of Quebec, considering that Bicknell's Thrush was not detected during the second atlas in the Magdalen Islands nor in several formerly occupied sites in the Gaspé Peninsula and Cote-Nord region (Aubry and Shaffer 2019; Figure 4).

BIOLOGY AND HABITAT USE

Bicknell's Thrush ecology is poorly known due to the remoteness of the areas it occupies, the dense vegetation and the steep slopes it selects, and the challenges involved in the observation of its behaviour once detected.

Bicknell's Thrush breeding biology has been intensively studied on some of the highest mountains in New England by the Vermont Center for Ecostudies, with long-term data from Mount Mansfield, Vermont (Wallace 1939; Hill *et al.* 2019; Townsend *et al.* 2020). Most research in Quebec has focused on populations at Mont Gosford, Massif du Sud, Mine Madeleine, Mont Copper, and the Laurentian Highlands (e.g., Aubry *et al.* 2011, 2016, 2018). Populations in the New Brunswick Highlands ecoregion received the most attention in the Maritime provinces (e.g., Nixon *et al*. 2001; Chisholm and Leonard 2008; McKinnon *et al.* 2014). Researchers from the Vermont Center for Ecostudies have conducted considerable research on wintering grounds, especially in the Dominican Republic (e.g., Townsend *et al.* 2010, 2011; McFarland *et al.* 2013, 2018).

Although mating associations involving one female and several males have been reported in other *Catharus* thrushes (e.g., Veery; Halley *et al*. 2016), this unusual mating system of female-defense polygynandry appears to be the norm for Bicknell's Thrush (Goetz *et al*. 2003). These highly dynamic mating associations include one female and up to four males, with some males feeding two broods simultaneously (Askanas 2012; Townsend *et al.* 2020; Y. Aubry unpubl. data). The number of provisioning males is negatively related to prey abundance (Strong *et al*. 2004). Males are not territorial in the classic sense, instead occupying home ranges that overlap extensively, whereas females defend territories against conspecific females, especially during nest-building and egg-laying (Townsend *et al*. 2020).

Life Cycle and Reproduction

The longevity record for Bicknell's Thrush is 11 years and 11 months (Lutmerding and Love 2013). Birds reach sexual maturity in their second calendar year, when they are just under 1 year old. Bird *et al.* (2020) estimated generation time to be 2.32 years on the basis of an annual survival rate of 0.58, age at first breeding of 1 year, and maximum longevity of 8.77 years.

The Bicknell's Thrush nests in dense conifer patches dominated by Balsam Fir, with White Birch (*Betula papyrifera*) as a secondary species, in both New Brunswick (n = 12; McKinnon *et al.* 2014) and Vermont (n = 103; Townsend *et al.* 2020). In Vermont, 87% of nests were built in Balsam Fir trees or shrubs (average height: 3.2 m ± 1.6 SD), on steep ground with slopes averaging 18.7° ± 10.4 SD. The nest is a bulky open cup, usually built against the trunk and supported by horizontal branches, and constructed by the female alone. New nests are built each year, and re-nesting following nest failure is frequent (Townsend *et al.* 2020). Although Bicknell's Thrush tends to have a clumped distribution owing to overlap of male home ranges, there is no evidence of active clustering of nests, based on minimal overlap among female territories (Townsend *et al.* 2020). In New Brunswick, female territories averaged 18.1 ± 5.3 ha (n = 9; Ward 2020), whereas in Quebec they averaged 13.9 ± 2.4 ha (n = 16; Aubry et al. 2011).

In Vermont, male Bicknell's Thrush return from spring migration in mid-May at the earliest, with females arriving about a week later (Townsend *et al.* 2020). Earliest nest construction was observed there on 1 June, with 71% of 89 clutches initiated during the first three weeks of June. Clutch size is 3–4 (mean: 3.6 ± 0.49 SD, n = 59), and incubation lasts 9–14 days (mean: 12 ± 1.6 SD, n = 8; Wallace 1939). Incubation and brooding are assumed by females only, whereas both sexes feed nestlings and fledglings. Males may feed two broods concurrently or consecutively (Goetz *et al*. 2003; Y. Aubry unpubl. data). In Vermont, nestlings fledged 9–13 days after hatching (mean 11.4 d ± 1.3 SD, n = 17), and young fledged from 70% of nests by 14 July (n = 53; Wallace 1939; Townsend *et al*. 2020). In Quebec, young fledged between 8 and 24 July (n = 6; Y. Aubry unpubl. data in Townsend *et al*. 2020). Re-nesting is common in Vermont, but only one case of a successful second brood has been reported (Townsend *et al.* 2020).

Apparent annual survival rate of adults in a Vermont population of Bicknell's Thrush was 0.61 (CI: 0.54–0.68; n = 178 adults) over a 14-year period (Hill *et al.* 2019). An apparent survival rate of 0.34 ± 0.06 for second-year birds and 0.48 ± 0.07 for adult (after second-year) birds was reported in the Gaspé Peninsula, Quebec (Townsend *et al.* 2020). In Sierra de Bahoruco, Dominican Republic, Townsend *et al.* (2020) derived a Cormack-Jolly-Seber survival estimate of 72.9% (± 14.3% SE), with mean parameter estimates for all models ranging from 68.4% to 79.7%. No data are available on juvenile survival rate owing to the challenge of resighting returning individuals. Philopatry is low in Vermont, based on a 2.6% return rate of individuals banded as nestlings or dependent fledglings (n = 115; Townsend *et al.* 2020).

Breeding productivity is relatively low. The average number of young fledged/nest was 2.1 ± 1.37 SD (range 0–4, n = 30) on Stratton Mountain, Vermont, and 1.5 ± 1.59 SD (range 0–4, n = 46) on Mount Mansfield, Vermont. Although these are minimum estimates, annual reproductive success of Bicknell's Thrush generally appears to be low. Townsend *et al.* (2020) indicate that "of 21 males with known paternity at nests in 1998 and 1999, 13 (62%) sired only one chick, 4 (19%) sired two chicks, 3 (14%) sired three chicks, and 1 (5%) sired four chicks".

Red Squirrel (*Tamiasciurus hudsonicus*) is a key nest predator of Bicknell's Thrush, and its numbers vary directly with the magnitude of cone crops, especially that of Balsam Fir. Daily nest survival rates in Vermont were 0.92 (14.7% for 12-day incubation and 11-day nestling periods) in years with low densities of Red Squirrel, and 0.79 (0.44% for 23-day breeding periods) in years with high squirrel densities (Townsend *et al.* 2020). The same phenomenon has been observed in Quebec (Aubry pers. comm. 2020). Nest predation and relatively wet weather in December-March influenced nest success and adult apparent survival on Mount Mansfield (Hill *et al.* 2019). These authors hypothesized that high Balsam Fir cone crops in late summer and early fall resulted in the high winter survival of squirrels, which in turn resulted in lower site fidelity by adult Bicknell's Thrush the following year as a consequence of lower nesting success. They further hypothesized that overwinter survival of adult Bicknell's Thrush was higher following wet winters, as a result of greater food abundance. Finally, nestlings may die from exposure during severe weather events (Townsend *et al*. 2020).

Habitat Requirements

<u>Breeding habitat</u>

Bicknell's Thrush is a habitat specialist that nests in dense, Balsam Fir-dominated stands subject to frequent natural disturbance (high winds, accumulation of winter ice, cool temperatures) or human activities creating similar forest characteristics (Townsend *et al.* 2020). Most breeding habitat occurs on high plateaus (e.g., Laurentian Highlands, New Brunswick's Highlands, Cape Breton Highlands) or at high elevations where forest stands dominated by Balsam Fir have not recently (<10 years) been altered by forest management (Connolly *et al.* 2002; Aubry *et al.* 2016, 2018; ECCC 2020). Locally, some individuals may occasionally breed near sea level in coastal spruce-fir stands in Quebec (Ouellet 1995), New Brunswick (Wilson pers. comm. 2021), and Nova Scotia (Erskine 1992; Whittam 2015).

Typical Bicknell's Thrush breeding habitat is characterized by dense dwarf Balsam Fir stands, or "krummholz", accompanied by White Birch primarily but also Red Spruce (*Picea rubens*), Black Spruce (*Picea mariana*), Mountain Ash (*Sorbus americana*), and Pin Cherry (*Prunus pensylvanica*). Forest stands with these characteristics are found at high elevations, on exposed ridgelines, or in areas altered by recurring natural disturbances (heavy winds, winter ice accumulation, cool sea breezes). Areas altered by human activities may also be used by Bicknell's Thrush >10 years after disturbance (e.g., by forest management) or along habitat edges (e.g., alpine skiing trails) (ECCC 2020; Townsend *et al.* 2020) and possibly access roads to wind farms (Artuso pers. comm. 2022).

Bicknell's Thrush has been reported in sites above 1100 m in elevation at the southern edge of its range, in the Catskills Mountains of New York. In Quebec's Laurentian Highlands, it was rarely detected below 800 m. In New Brunswick's Highlands, 67% of the birds detected by Nixon *et al*. (2001) occupied sites above 600 m, but some were detected at elevations as low as 457 m. In Cape Breton, Nova Scotia and along the Bay of Fundy, in New Brunswick, Bicknell's Thrush is occasionally found in coastal spruce-fir stands close to sea level (Erskine 1992; Stewart *et al.* 2015). Some birds were also detected in coastal habitat in Quebec (e.g., Percé and Île Bonaventure; eBird 2021; Figure 6).

Bicknell's Thrush radio-tracked in managed forests used some pre-commercially thinned areas within their home range, although unthinned stands dominated use (Aubry *et al.* 2011). Chisholm and Leonard (2008) reported the highest abundance in regenerating stands 11–13 years after clear-cutting in New Brunswick, where pre-commercial thinning had a negative effect on breeding numbers at both local and stand levels. In Cape Breton, Nova Scotia, 78% of Bicknell's Thrush were detected in unmanaged fir-dominated stands, with the remainder in regenerating industrial forest (Busby pers. comm. in Townsend *et al.* 2020). In the Laurentian Highlands, Bicknell's Thrush showed a preference for 20–25 year-old, post-harvest stands on hilltops with no recent signs of timber harvesting or silvicultural treatments (Desrochers *et al*. 2017; Aubry *et al*. 2018). Elsewhere in Quebec (Charlevoix, Gaspé Peninsula, and the Eastern Townships), the species has been reported in stands with average canopy heights of 7.5, 5.3, and 9.0 m, respectively (Rompré *et al.* 1999), suggesting that it also occupies relatively old forest stands. In New Brunswick, Bicknell's Thrush occupied sites with significantly higher densities of Balsam Fir stems in the 5–10 cm dbh class (Nixon *et al*. 2001; Chisholm and Leonard 2008) and has been reported in older, unthinned stands on mountain tops in the Christmas Mountains and Kedgwick Highlands (Torrenta 2021a).

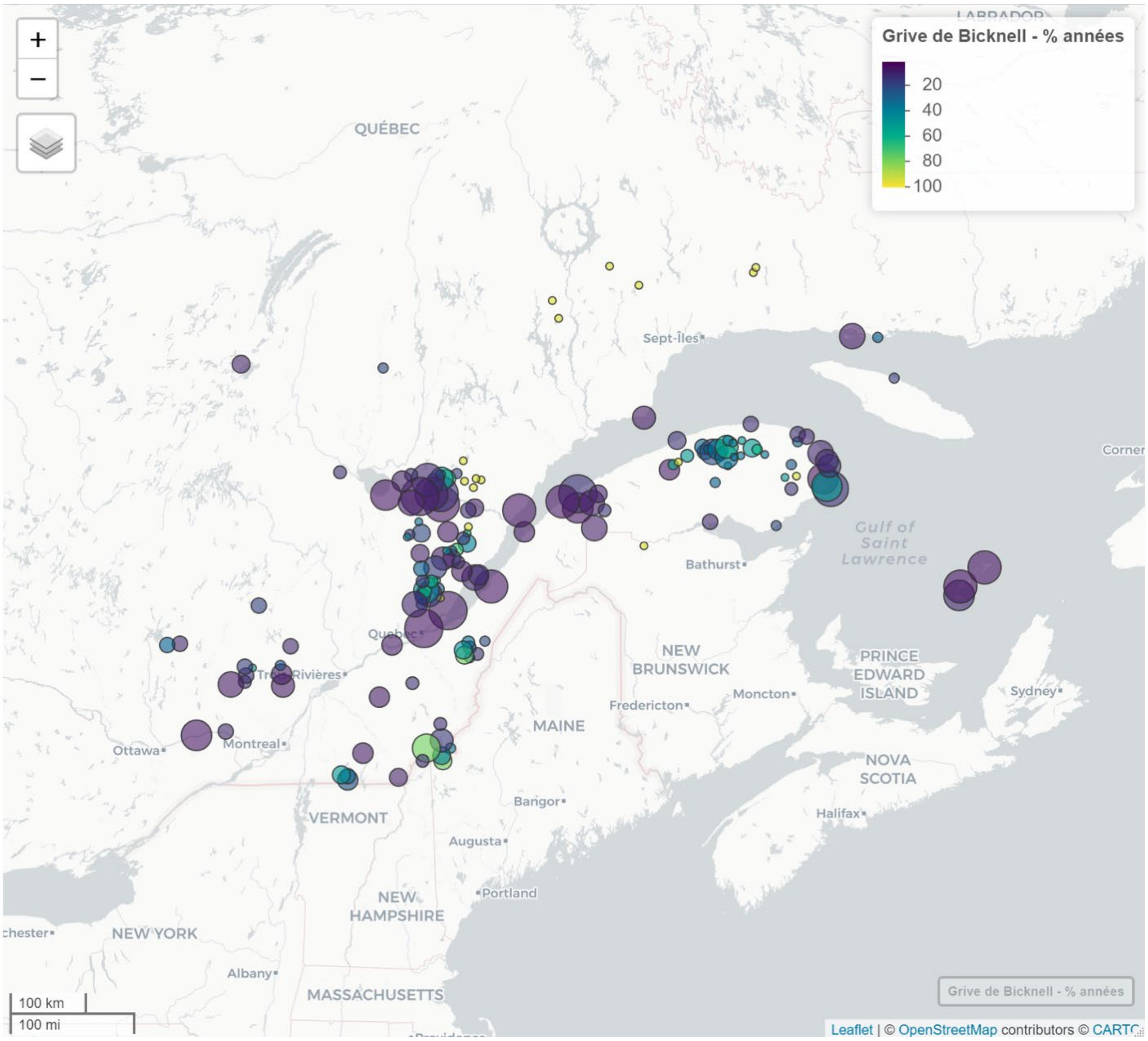

Figure 6. Records of detections of Bicknell's Thrush by amateur birdwatchers in Quebec during the period 1970–2020, from 10 June to 10 August each year from eBird (2021) and ÉPOQ (J. Larivée and Regroupement QuébecOiseaux). Only observations made east of 76.5ºW and south of 51ºN are shown. Warmer colours (increasing from purple to green to yellow) indicate the proportion of years in which Bicknell's Thrush was detected for each 10 x 10 km square visited by observers. Squares with no observations are not shown. Dot size is proportional to the number of bird lists submitted per square (A. Desrochers unpubl. data).

Migration habitat

Although habitat used by Bicknell's Thrush during migration remains poorly documented, scattered reports suggest that it uses a wider range of vegetation types, as observed in many songbirds. For example, Bicknell's Thrush is frequently captured by bird banders in coastal Virginia in upland shrub and dune scrub forest (Wilson and Watts 1997). In Montreal, habitat used by three fall migrating individuals at the McGill Bird Observatory included dense shrubland dominated by hawthorn (*Crataegus* sp.), buckthorn (*Rhamnus cathartica* and *R. frangula*), and Staghorn Sumac (*Rhus typhina*), with small patches of mature stands dominated by White Ash (*Fraxinus americanus*) and Sugar Maple (*Acer saccharum*; Morales pers. comm. 2021). Three fall records of Bicknell's Thrush at Charron Island, adjacent to Montreal Island, occurred in open stands co-dominated by White Ash and poplar (*Populus* spp.), with a dense understorey of Staghorn Sumac (Gauthier pers. comm. 2021). Two spring records (assumed to be migrants) at Observatoire des oiseaux de Rimouski occurred in dense thickets dominated by Speckled Alder (*Alnus rugosa*), Red-osier Dogwood (*Cornus stolonifera*), and willow (*Salix* spp).

<u>Winter habitat</u>

Bicknell's Thrush winter habitat is generally characterized as mesic or wet mountain broadleaf montane forest, and the Dominican Republic comprises more than half of its predicted wintering habitat (Townsend *et al.* 2020). Both sexes defend small territories in dense vegetation on the wintering grounds, with only 2.7–5.6% of individuals moving amongst different areas (Townsend *et al.* 2010). Evidence exists for sexual habitat segregation, with male-biased sex ratios (74% males) in high-elevation cloud forests and a nearly even ratio (53% males) in rainforest at lower elevations (Townsend *et al.* 2012). McFarland *et al.* (2013) mapped potential habitat in the Greater Antilles and found that sites used by Bicknell's Thrush had a higher and denser forest canopy, as well as a denser understorey, than unused sites. Most sites (85%) used by wintering birds were in broadleaf forest, with 12% in mixed forest. Occupancy was higher in more mature seral stages and at wetter sites. Townsend *et al.* (2009) noted that birds foraging in cloud forest roosted in nearby pine forest (within 100 m), apparently to avoid arboreal predators (mainly introduced rats).

Movement, Dispersal, and Migration

Bicknell's Thrush is a Neotropical, nocturnal migrant. Southbound migrants tracked with geolocators departed between 30 September and 12 October from several sites between the Catskill Mountains and the Gaspé Peninsula (Townsend *et al*. 2020). At Forêt Montmorency in the Laurentian Highlands, radio-tagged individuals departed as late as 7 October (Desrochers *et al*. 2017), which is broadly consistent with dates when fall migrants have been reported in Montreal.

Most fall migrating Bicknell's Thrush move south along the Atlantic coast of the United States to Virginia. They then follow an elliptical trajectory between the southeastern United States and the Greater Antilles, departing on an overwater flight to the Greater Antilles. Northbound spring migrants appear to move directly up the east coast from Florida to Virginia, with twice as many birds reported along that segment of the Atlantic coast during the spring than in the fall (Townsend *et al.* 2020). Bicknell's Thrush fall migrants tagged in the Laurentian Highlands and radio-tracked with Motus (Taylor *et al*. 2017) flew closer to the Atlantic coast than either Swainson's (*C. ustulatus*) or Gray-cheeked Thrush (Bégin-Marchand *et al*. 2020). Mean duration of fall migration was 29 ± 10 days, including stopovers varying between 6 and 33 days in duration, in late October and early November (Townsend *et al*. 2020). Spring migrants depart the Greater Antilles between 28 April and 7 May, with a mean duration of northbound migration of 17 ± 4 days (Townsend *et al.* 2020). No key spring stopover sites have been reported (Townsend *et al.* 2020).

As with most songbird species, post-natal dispersal likely accounts for most Bicknell's Thrush inter-population movements. Studds *et al.* (2012) mapped deuterium ratios in tail feathers and estimated that nearly 70% of post-natal dispersal movements of 114 individuals captured at 25 montane sites were less than 200 km in distance, with a few juvenile individuals dispersing as far as 700 km. A yearling male dispersed 17.2 km between breeding seasons (Townsend *et al.* 2020), although most dispersal movements by adults were considerably shorter. The mean distance between nests used by 26 banded females in successive years in Vermont was 182.9 m (± 267.8 SD; Townsend *et al.* 2020).

Physiology

Bicknell's Thrush appears to have a lower rate of oxygen consumption with decreasing air temperature than the other *Catharus* thrush species that occur in northeastern North America (Holmes and Sawyer 1975). This may be a metabolic adaptation to more severe weather conditions prevailing in summer in subalpine breeding habitats. Levels of mercury acquired from atmospheric deposition in Bicknell's Thrush blood sampled at Mount Mansfield, Vermont, are below those reported to negatively impact physiology or reproduction in other invertivorous passerines (Rimmer *et al.* 2005, 2019).

Diet

Bicknell's Thrush forages on arboreal invertebrates during the breeding season, including ants, beetles, and Lepidopteran larvae (Wallace 1939), likely including Spruce Budworm (*Choristoneura fumiferana*). As with other migratory *Catharus* thrushes, this species may be frugivorous in late summer and during fall migration, although this is not confirmed in the literature. Bicknell's Thrush feeds on both arthropods and fruits on the wintering grounds. Males tend to favour habitat rich in arthropods, whereas lower-elevation habitat selected by females is richer in soft-bodied fruit (Townsend *et al.* 2012).

Interspecific Interactions

<u>Predators</u>

Predation of adult Bicknell's Thrush is relatively rare on Canadian breeding grounds, although Townsend *et al.* (2020) documented predation of adults by Sharp-shinned Hawk (*Accipiter striatus*) and possibly Long-tailed Weasel (*Mustela frenata*). Northern Saw-whet Owl (*Aegolius acadicus*) may depredate fledglings or adults, as suggested by the fact that it is actively mobbed by adult Bicknell's Thrush (Townsend *et al*. 2020).

Both direct (McFarland and Rimmer 2002) and indirect evidence indicates that Red Squirrel is a key Bicknell's Thrush nest predator, especially in years following large Balsam Fir cone crops (Hill *et al*. 2019). Nest monitoring with cameras at Mine Madeleine and Mont Gosford, Quebec, revealed predation by Red Squirrel, Sharp-shinned Hawk, American Marten (*Martes americana*), and Deer Mouse (*Peromyscus maniculatus*) (Y. Aubry unpubl. data). Other nest predators include Long-tailed weasel, Northern Saw-whet Owl, Boreal

Owl (*Aegolius funereus*), Mink (*Neovison vison*), Eastern Chipmunk (*Tamias striatus*), and Canada Jay (*Perisoreus canadensis*) (Townsend *et al.* 2020).

Nocturnal predation by the introduced Black (*Rattus rattus*) and Norway Rat (*R. norvegicus*) is thought to represent a significant cause of mortality of wintering adults in the Dominican Republic (Townsend *et al.* 2009; see **Threats**).

<u>Non-predatory interspecific interactions</u>

Aggressive interactions have been documented between Swainson's and Bicknell's Thrushes (Able and Noon 1976), and the latter has been displaced from song perches by American Robin (*Turdus migratorius*) and White-throated Sparrow (*Zonotrichia albicollis*; Townsend *et al.* 2020). In contrast, Aubry *et al.* (2016) found extensive co-occurrence of Bicknell's and Swainson's Thrushes at Mont Gosford and Massif-du-Sud, Quebec. Recent population trends (2011–2019) from the US Mountain Birdwatch Program (n = 750 point count stations spread across the range in the United States) suggest a downward shift in the elevational range occupied by Swainson's Thrush and a 24.6% decline in abundance across New England (J.M. Hill unpubl. data). A playback experiment suggested asymmetrical interspecific aggression by Swainson's Thrush towards Bicknell's Thrush (Freeman and Montgomery 2016), but this was based on a small sample size.

Fitzgerald (2017) compared the ecological niches of Bicknell's and Gray-cheeked Thrushes and concluded that Bicknell's Thrush nested in warmer, wetter sites with a high abundance of Balsam Fir, whereas Gray-cheeked Thrush was more often found in Black Spruce.

There is no evidence of non-predatory interspecific interactions during the nonbreeding season.

Adaptability

As a habitat specialist, Bicknell's Thrush appears to be highly affected by forest management practices such as those applied in the Maritime provinces (Whittam 2015). It has been shown to nest in post-harvest conifer stands, especially mid-age (11–13 year) clear-cuts with dense Balsam Fir regeneration (Chisholm and Leonard 2008). Among boreal bird species, Bicknell's Thrush is considered one of the most vulnerable to climate change (Stralberg *et al*. 2019) owing to the projected decline of its habitat and its demographic sensitivity (low population size and high variability in reproductive success). Individuals defending territories in cloud forest on the wintering grounds tend to roost in nearby pine stands, apparently in response to predation risk from arboreal rats (Townsend *et al*. 2009).

Limiting Factors

The main limiting factors for Bicknell's Thrush appear to be its highly specialized ecological requirements that limit habitat availability on both breeding and wintering grounds, and its relatively low productivity (Townsend *et al*. 2012, 2020). Low productivity and the female-defense polygynandry mating system (Goetz *et al*. 2003) probably stem from the short breeding season associated with the harsh weather conditions experienced by this species.

The breeding habitat of Bicknell's Thrush is geographically restricted to high elevations and areas subject to certain chronic natural disturbances (strong winds, heavy ice, or cool sea breezes). The species' strong association with Balsam Fir also limits habitat availability on high plateaus, where spruces often dominate (Aubry pers. comm. 2020). Bicknell's Thrush appears to be associated with relatively narrow successional windows in New Brunswick (Chisholm and Leonard 2008) and the Laurentian Highlands (Aubry *et al.* 2018), although recent data from Torrenta (pers. comm. 2021) suggest that they may use older stands. The fact that the number of provisioning males at nests decreases with food abundance (Strong *et al.* 2004) suggests that abiotic conditions (short breeding season, inclement weather) may also be limiting. Finally, nest predation by Red Squirrel can be very intense every second year, as a function of the periodicity of Balsam Fir masting (Hill *et al.* 2019). Red Squirrel populations are also influenced by spruce masting, whose cones can be stored in middens, unlike fir cones (Aubry pers. comm. 2021). Wintering habitat is spatially limited (about 33,000 km^2; McFarland *et al*. 2013), and only about 30% is protected.

The current and emerging outbreak of Spruce Budworm in Eastern Canada has the potential to severely reduce Bicknell's Thrush habitat quality over the short term. Spruce Budworm is a defoliating insect whose main host is Balsam Fir (Hennigar *et al.* 2008), and severe outbreaks may kill both regenerating and mature fir trees, as observed on the north shore of the St. Lawrence River (Poulin pers. comm. 2021). Bicknell's Thrush habitat near Monts Valin and in the Gaspé Peninsula suffered severe budworm outbreaks in 2020 (MFFP 2020; Figures 4, 7). Over the longer term, the effects of this outbreak will depend on the vigour of future Balsam Fir regeneration, which will itself be influenced by climatic changes.

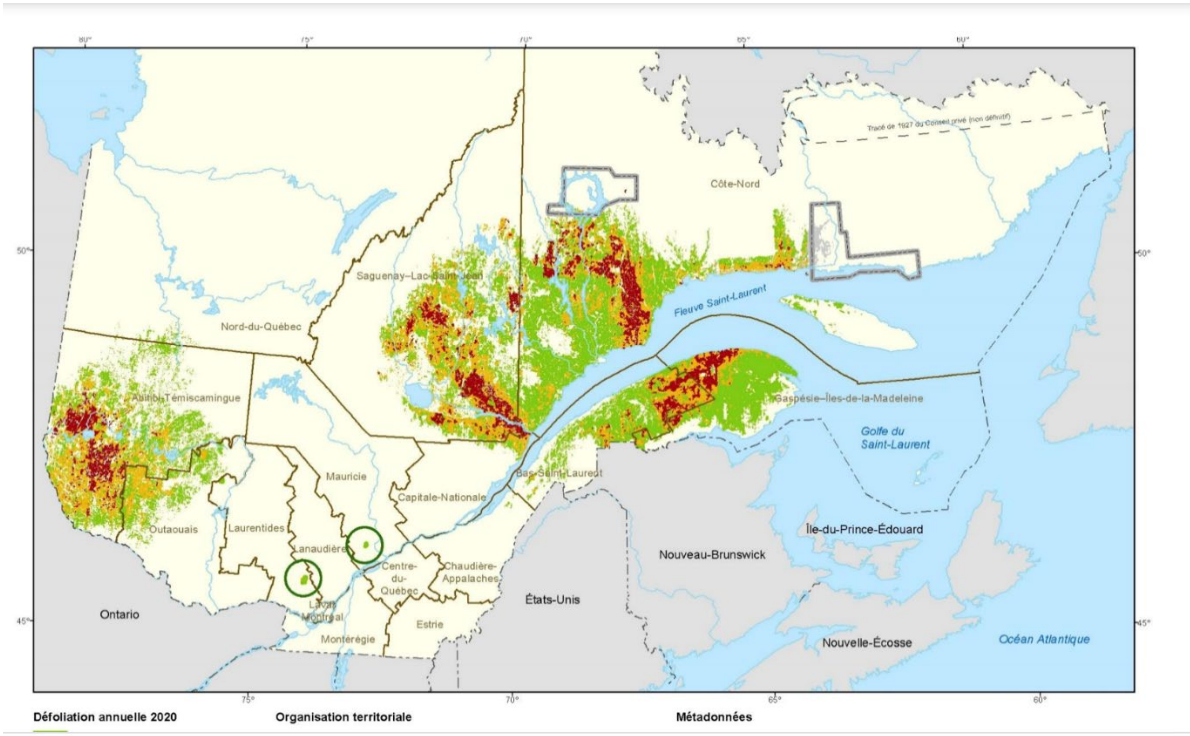

Figure 7. Intensity of forest defoliation by Spruce Budworm in Quebec in 2020, based on aerial surveys by the Quebec Ministère des Forêts, de la Faune et des Parcs (MFFP 2020). Green indicates areas of light defoliation, orange indicates moderate defoliation, and red indicates severe defoliation.

POPULATION SIZES AND TRENDS

Data Sources, Methods, and Uncertainties

It is challenging to survey breeding Bicknell's Thrush, because its breeding areas are remote and its vocal activity is mostly crepuscular (Ball 2000; Townsend *et al.* 2020). Bouts of calling and singing are normally of short duration, about 15–20 min (Townsend *et al*. 2020). This makes it difficult to monitor the species using standardized roadside count protocols that rely on morning vocalization. In addition, calls are much more frequent than songs (Aubry pers. comm. 2021), and response to conspecific playbacks has been shown to be inconsistent when compared with Automatic Recording Unit (ARU) recordings for the same sites (Torrenta pers. comm. 2021). Complex mating associations and singing by females further complicate interpretation of vocalisations in estimating numbers of pairs. The male-biased sex ratio of Bicknell's Thrush might suggest that populations are somewhat buffered against male-biased declines, but the observation that more provisioning males are present at nests when food abundance is lower (Strong *et al.* 2004) suggests that several provisioning males may be required for successful reproduction in such circumstances. Hence, isolated individuals likely represent nonbreeding males or females.

The North American Breeding Bird Survey

The North American Breeding Bird Survey (BBS) is a North America-wide citizen science program that monitors population trends for birds in North America (Hudson *et al.* 2017; Sauer *et al.* 2017). Skilled volunteers are assigned to a roadside route 39.2 km long, composed of fifty 3-minute point counts located at 0.8-km intervals. All birds heard or seen within 400 m are recorded at each stop (Hudson *et al.* 2017).

As relatively few roads reach high-elevation sites where most Bicknell's Thrush habitat occurs, roadside surveys such as the BBS do not sample much of the habitat used by this species. Bicknell's Thrush population trends are estimated from observations on 14 BBS routes in Canada with long-term data and 9 routes with short-term data (2009–2019), including 3 routes in Quebec and 6 in Nova Scotia (Table 2; Smith *et al.* 2020). Only 5 routes in the United States recorded Bicknell's Thrush in 2009–2019. BBS data were insufficient to document provincial population trends in New Brunswick (Smith pers. comm. 2021). The relatively low statistical reliability of the resulting Bicknell's Thrush population trend estimates is attributable to these low sample sizes. Short-term (5- and 10-year) trends may therefore be better estimated by interpolation based on the long-term annual rate of decline, in line with IUCN guidelines (IUCN Standards and Petitions Committee 2022). Results of both analytical approaches are presented below.

Table 2. Short-term (2009–2019) and long-term (1970–2019) population trends for Bicknell's Thrush in Canada, based on North American Breeding Bird Survey data. Data were insufficient to estimate population trends for New Brunswick (A. Smith unpubl. data).

Region	Annual % rate of change (95% lower, upper CI)	Cumulative % change (95% lower, upper CI)	Probability of decline >30%	No. of routes	Reliability
2009–2019					
Canada	-7.40 (-20.73, 0.99)	-53.65 (-90.20, -10.34)	0.79	9	Low
Quebec	-7.63 (-20.73, 1.34)	-54.78 (-90.20, 14.21)	0.79	3	Low
Nova Scotia	-7.79 (-21.50, 1.74)	-55.55 (-91.11, 18.78)	0.79	6	Low
1970–2019					
Canada	-4.10 (-8.67, -0.80)	-87.17 (-98.83, -32.66)	0.98	14	Low
Quebec	-4.09 (-8.73, -0.59)	-87.07 (-98.86, -25.15)	0.97	8	Low
Nova Scotia	-4.40 (-9.05, -0.72)	-88.96 (-99.04, -29.73)	0.97	6	Low

Species-specific monitoring programs

Specific survey methods designed to monitor birds in high-elevation habitat, including the High Elevation Landbird Program (HELP; Campbell and Stewart 2012) and Mountain Birdwatch (MBW; Hill and Lloyd 2017), have proven useful in surveying Bicknell's Thrush. HELP surveys were initially undertaken following predetermined 1 km routes, stopping every 250 m to conduct a 10-minute point count (Campbell and Stewart 2012). HELP was later modified to meet the standardized protocol of the range-wide Mountain Birdwatch 2.0 and was combined with that program in 2016 (Kouwenberg 2020). The MBW morning survey protocol was designed to detect the minimum annual change of 3% over 30 years identified in the 2010 Bicknell's Thrush Conservation Action Plan (IBTCG 2010). The MBW protocol consists of four consecutive 5-minute counts at each survey point, for a total sampling period of 20 minutes per point. During the first 10 minutes of the survey, observers track individual Bicknell's Thrush within four distance categories on a minute-by-minute basis. For the final 10 minutes, Bicknell's Thrush are counted using the same method as the other MBW focal species (Kouwenberg 2020). The MBW 2.0 protocol was first applied in New Brunswick in 2016, and then in Nova Scotia in 2018 and 2019 (Kouwenberg 2020), precluding its use in calculating meaningful 10-year population trends here. From 2018 to 2020, Birds Canada also deployed automated recording units (ARUs) on Cape Breton and Scatarie Islands, Nova Scotia, and in northern New Brunswick (Kouwenberg 2020; Torrenta 2021a). In Quebec, the MBW 2.0 protocol was applied for a pilot year but was replaced by point count surveys at focal sites because the MBW yielded too few detections (Aubry pers. comm. 2021). However, recent ARU data suggest that several sites where conspecific playbacks had yielded no response may actually host breeding individuals (Torrenta pers. comm. 2021).

Trends from ÉPOQ and eBird databases

In Quebec, population trend data can be derived from observation checklist data from amateur birdwatchers in ÉPOQ (Étude des populations d'oiseaux du Québec; J. Larivée and Regroupement QuébecOiseaux, ÉPOQ 2021) and eBird. eBird is an online checklist program widely used by birders for reporting field observations (eBird 2021). The program was established in 2002, and its use has increased markedly in recent years. Data from ÉPOQ databases have been incorporated into eBird, and although data remain weighted to recent years, eBird records are informative regarding recent distribution patterns and notable concentrations of individuals.

ÉPOQ and eBird can be subsampled to reflect the breeding period of Bicknell's Thrush, and latitudinal and longitudinal limits of its breeding range. André Desrochers performed such an analysis for the purposes of this report (A. Desrochers unpubl. data). Although records of rare species are validated by regional ÉPOQ coordinators and eBird volunteer reviewers, mistakes in identifying Bicknell's Thrush are still possible, as with all survey methods presented here.

<u>Breeding Bird Atlases</u>

Breeding Bird Atlases are large-scale citizen science projects that document the distribution and relative abundance of breeding birds at provincial or regional scales. Each atlas is composed of a contiguous grid of 10 x 10 km atlas squares. Surveys are volunteer-based, with skilled birders recording evidence of breeding (possible, probable, or confirmed) for all bird species within each atlas square sampling unit of 100 km^2. During atlassing, volunteers are also encouraged to perform point counts and to document nest records.

Quebec (Robert *et al*. 2019) and the Maritime provinces (Stewart *et al*. 2015) have each completed a second breeding bird atlas since the last status report (COSEWIC 2009), allowing for regional estimations of change in Bicknell's Thrush distribution and probability of occurrence between 1984–1989 and 2010–2014, and between 1986–1990 and 2006–2010, respectively. However, large portions of potential Bicknell's Thrush habitat may be under-sampled by these atlases owing to difficulty of access, especially in parts of Quebec (Figure 3.1 in Robert *et al*. 2019).

Abundance

COSEWIC (2009) provided an estimate of the Canadian Bicknell's Thrush population of 40,570–49,258 mature individuals, developed by extrapolating bird densities calculated from survey point counts across Bicknell's Thrush habitat, as determined from a range-wide breeding habitat model. A more recent analysis of HELP results provided population estimates of about 2851 (95% CI: 1137–10,652) mature individuals in New Brunswick and 3848 (95% CI: 1823–7049) in Nova Scotia (Campbell and Stewart 2012). For the United States, a population estimate for 2016 (71,318 individuals; 95% CI: 56,788–90,219) was calculated using data from the Mountain Birdwatch program, and a global estimate of ~120,000 mature individuals was proposed (Hill and Lloyd 2017).

An updated Bicknell's Thrush population estimate for Quebec was developed for this report by Y. Aubry, based on point count survey data and estimated areas of habitat above or below 800 m in each major habitat patch or region (Table 1; Aubry pers. comm. 2021). This estimate was obtained by extrapolating from densities estimated based on point counts in the corresponding patch or region (COSEWIC 2009). For each patch or region, minimum and maximum density estimates from distinct point count surveys were used to obtain an estimated range of population numbers (see Table 1). Where no survey data were available, but Bicknell's Thrush was known to be present, the density recorded in the closest patch or region with comparable habitat quality was used. Using this approach, the Bicknell's Thrush population in Quebec was initially estimated to be 27,986–119,347 mature individuals (Aubry pers. comm. 2021). However, the point count data used to produce these estimates were 7–20 years old (Table 1), necessitating a correction to the short-term declining trend reported by the BBS (-54.78%; Table 2). Across Canada, 10-year rolling trends showed a mean rate of decline exceeding -30% by 2008 and -50% by 2017 (Figure 8). Applying a reduction of about 50% resulted in a final population estimate of about 14,000–59,700 mature individuals in Quebec (Table 3).

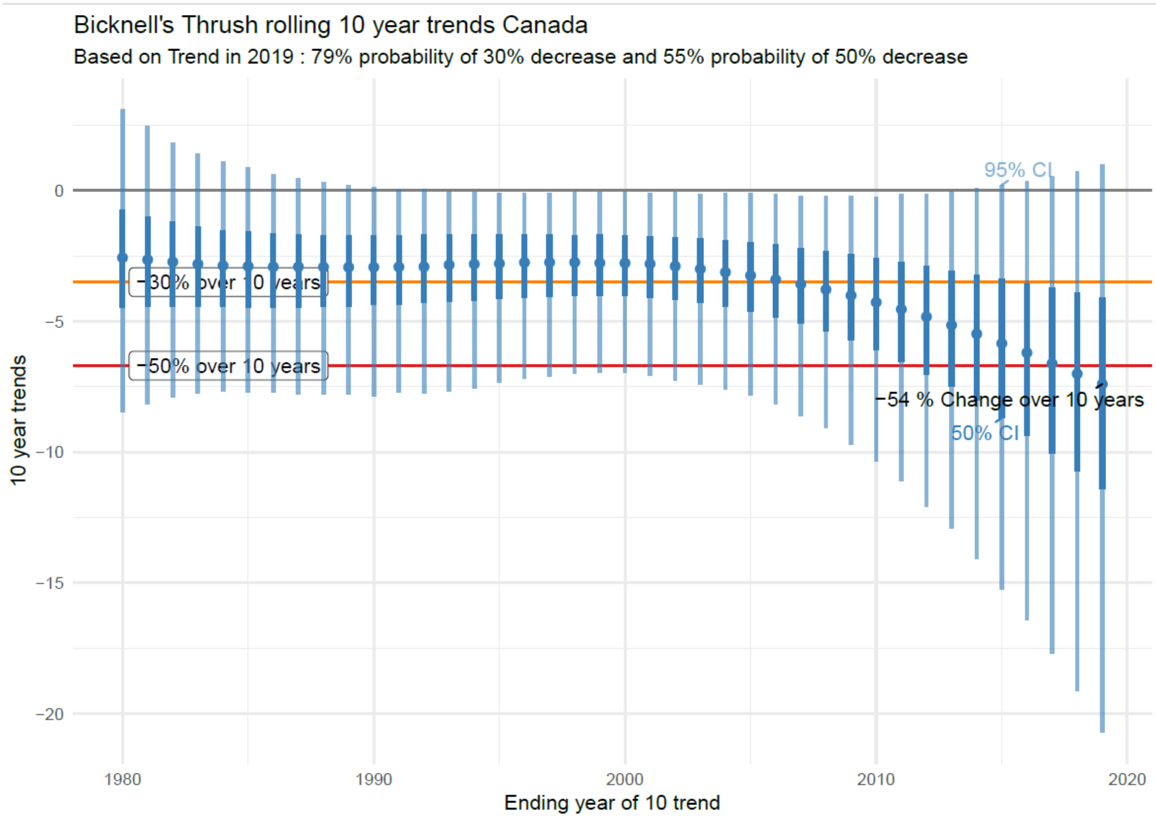

Figure 8. Rolling 10-year trends of Bicknell's Thrush population change across Canada from 1970–1980 through to 2009–2019, based on Breeding Bird Survey data (A. Smith unpubl. data 2020). The vertical axis represents the average annual percent change in population size over a 10-year period. The horizontal axis represents the last year of the 10-year rolling trends (e.g., 2019 is the trend for 2009–2019). Orange and red horizontal lines depict 30% and 50% cumulative short-term decline rates, which represent COSEWIC thresholds for listing a species as Threatened and Endangered, respectively. Vertical bars represent the 50% (broad, dark blue) and 95% (narrow, light blue) credible intervals.

Table 3. Estimated number of mature Bicknell's Thrush individuals in Canada by province, based on point count data from Quebec (see Table 1), the relative number of occupied squares reported in the second breeding bird atlases of Quebec (Robert *et al.* 2019) and the Maritime provinces (Stewart *et al.* 2015), and accounting for a 50% decline since 2009 (see Figure 8).

Province	Number of mature individuals	% of the Canadian population
Quebec	14,000–59,700	65.6%
New Brunswick	5,100–21,800	24.0%
Nova Scotia	2,200–9,500	10.4%
Canada total	**21,300–91,000**	**100%**

Bicknell’s Thrush was recorded in 30 breeding bird atlas squares in New Brunswick (24% of atlas squares occupied in Canada), 13 in Nova Scotia (10.4%; Stewart *et al.* 2015; Figure 5), and 82 in Quebec (65.6%; Robert *et al.* 2019; Figure 4). Assuming no significant differences in the density of breeding adults among provinces and equal probability of detection in each province, this produced population estimates of 5,100–21,800 mature individuals for New Brunswick and 2,200–9,500 for Nova Scotia. However, the assumption of equal densities across provinces does not seem to hold for Nova Scotia (Table 1), so the estimate of the number breeding in that province is very likely to be an overestimate. Totalling these figures yields a Canadian Bicknell’s Thrush population estimate of about 21,300–91,000 mature individuals (Table 3). Partners in Flight does not provide a population estimate for this species, and the proportion of the global population that occurs in Canada is unknown but may be between one-third and one-half (based on Aubry and Shaffer 2019).

Fluctuations and Trends

<u>Population fluctuations</u>

Hill *et al.* (2019) have shown that the apparent survival rate of Bicknell’s Thrush on Mount Mansfield, Vermont, fluctuated with cycles in annual cone production by Balsam Fir (see **Life Cycle and Reproduction**), but Bicknell’s Thrush is not known to exhibit extreme population fluctuations.

<u>Long-term historical trends</u>

For breeding Bicknell’s Thrush in Canada, the BBS indicates a long-term (1970–2019) annual rate of decline of 4.1% (95% CI: -8.67, -0.80) (Table 2; Figure 9), which corresponds to a cumulative decline of 87.17% (95% CI: -98.83, -32.66) over that 49-year period (Smith pers. comm. 2020). This long term-trend is one of a continuing gradual decline, with occasional small peaks in numbers counted (e.g., in 2002, 2007; Figure 9). ÉPOQ and eBird data suggest a more complex long-term trend in percent detections in Quebec (Figure 10; A. Desrochers unpubl. data), with an initial period of relatively numerous detections (1970–1977), then a period with relatively few detections until the mid-1990s, followed by a period with more numerous detections and another decline starting in 2013. However, as Bicknell’s Thrush was first recognized as a separate species in 1995, identification of birds recorded prior to that date may have been inconsistent, and interest after 1995 may have driven birdwatchers to search for this “new” species, contributing to the increase in sightings.

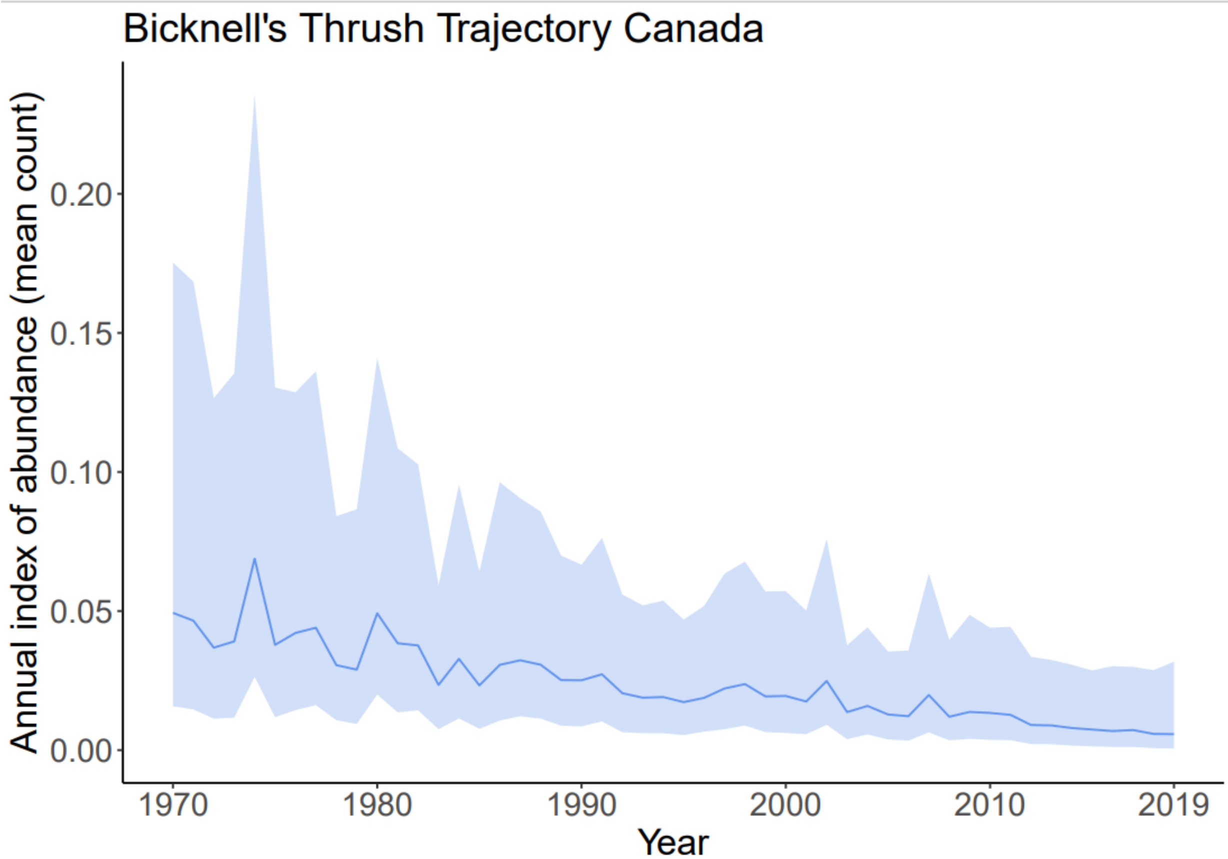

Figure 9. Annual index of population abundance for Bicknell's Thrush in Canada, based on Breeding Bird Survey data from 1970 to 2019 (n = 14 routes). The GAM (generalized additive model) trend represents the best curvilinear fit of data. Blue shading shows 95% credible intervals for the GAM trend (A. Smith unpubl. data).

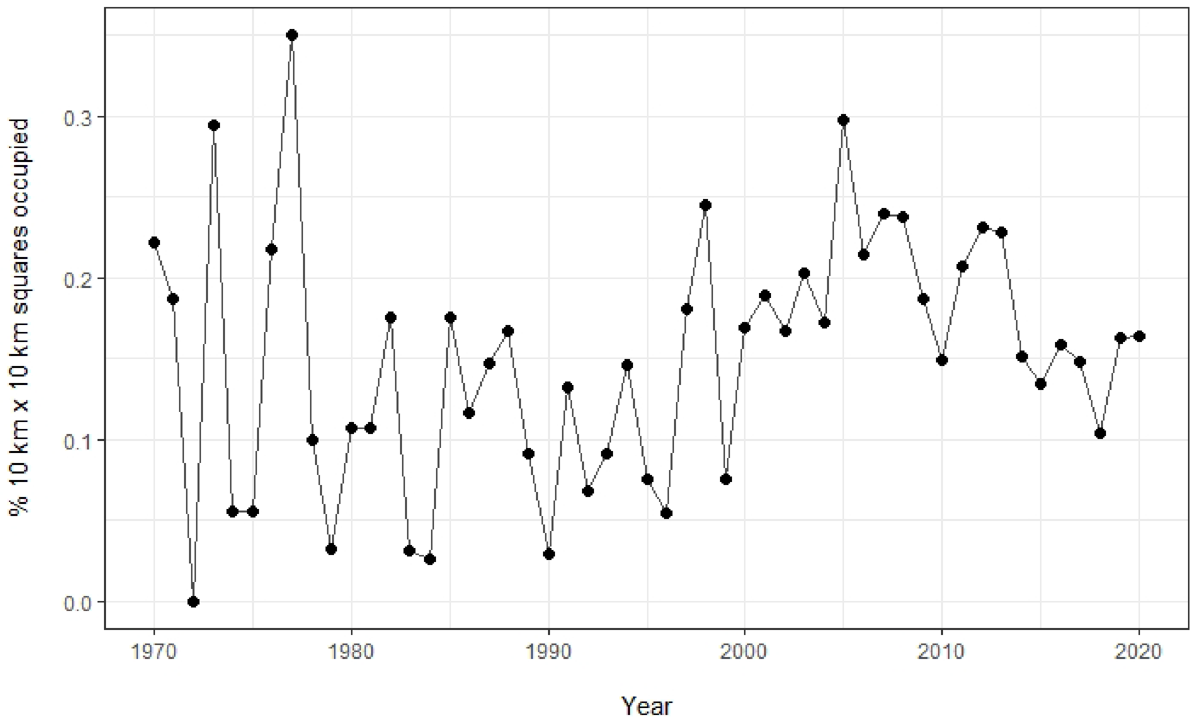

Figure 10. Trends in number of Bicknell's Thrush detections by amateur birdwatchers in Quebec during the period 1970–2020, from 10 June to 10 August each year, from eBird (2021) and ÉPOQ (J. Larivée and Regroupement QuébecOiseaux) databases. Only birds detected east of 76.5ºW and south of 51ºN were included. Points represent the percentage of 10 x 10 km squares visited by observers in which Bicknell's Thrush were present in each year, out of all squares in which Bicknell's Thrush were recorded at least once during the 50-year period (A. Desrochers unpubl. data).

Short-term trends

Bicknell's Thrush population trends are not available for the past 10-year period (2009–2019) from species-specific survey programs as HELP surveys in the Maritime provinces were replaced by MBW surveys beginning in 2013 (Kouwenberg 2020). However, HELP surveys showed marked annual decreases of 7.4% in Nova Scotia and 11.5% in New Brunswick over the latest 10-year period for which data are available (2002–2011; Campbell 2014). Bicknell's Thrush numbers have continued to decline in Nova Scotia in recent years, with only four birds detected on MBW surveys in 2015, two in 2016, and none in 2017, the last year that surveys were conducted (Kouwenberg 2020), although 25 had been detected on these routes in 2013 (Campbell 2014). During the period 2016–2019, none were recorded at Money Point in extreme northern Cape Breton Island, previously the regional stronghold with the highest breeding density in Atlantic Canada (Kouwenberg 2020). However, numbers recorded on MBW surveys in northern New Brunswick appear to have been relatively stable over the period 2016–2020 (Torrenta 2021b), following sharp declines detected there by HELP surveys (above).

In Quebec, an analysis of ÉPOQ and eBird data indicates a slight decline in detections of Bicknell's Thrush over the period 2013–2020, following a period of increase that seemed to begin in the mid-1990s (Figure 10). However, ÉPOQ and eBird data are collected from sighting records of amateur birdwatchers who were not specifically surveying for Bicknell's Thrush in appropriate habitat and may be specifically searching for this species (see also **Long-term Trends,** above), so they must be considered with caution.

In Canada, the annual rate of decline recorded by the BBS over 2009–2019, was -7.4% (95% CI: -20.73, 0.99), corresponding to a cumulative decline calculated using that annual rate of -53.7% (95% CI: -90.20, -10.34) (Smith *et al.* 2020; Table 2, Figure 11). The comparable rate of decline over the 5-year period of 2014–2019 was -31.9% (95% CI: -68.7%, +5.0%; Smith *et al.* 2020). Similar rates of decline were reported for Quebec, Nova Scotia, and adjacent northeastern United States (Smith *et al.* 2020), but as BBS trends at the provincial or national level were not statistically significant and were based on small sample sizes, they should be interpreted with caution. Indeed, no Bicknell's Thrush were detected on Canadian BBS routes in 7 out of the 10 years during the period 2009–2019. Interpolation of the 10-year trend based on the 4.1% long-term annual rate of decline yields an alternate short-term decline estimate of -34.2% (95% CI: -59.6, -7.8) over 2009–2019.

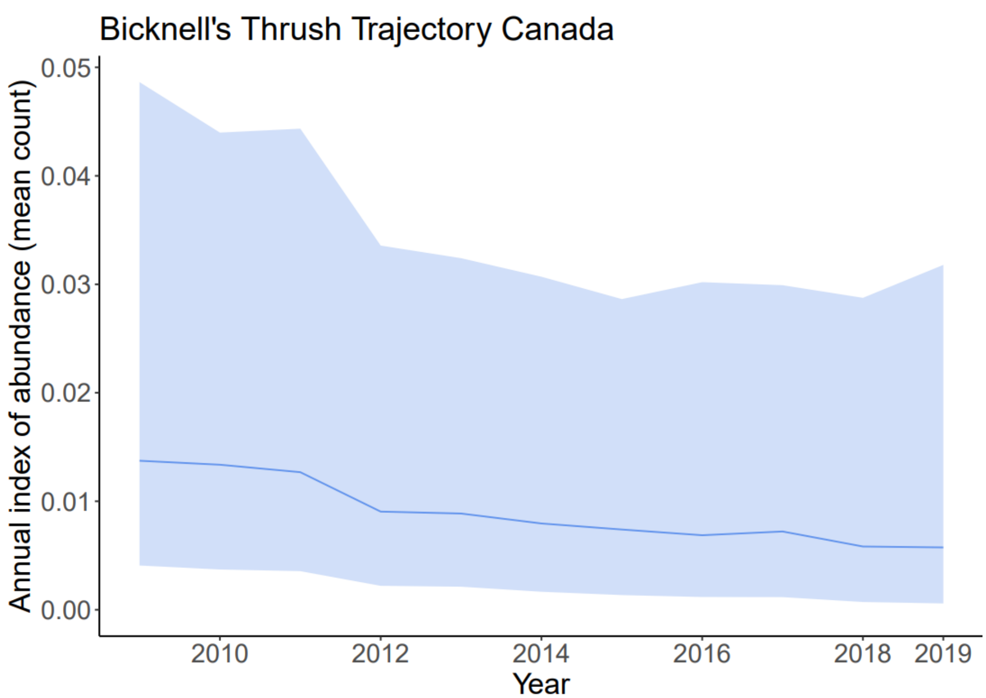

Figure 11. Short-term (2007–2019) annual rates of population change estimated from Breeding Bird Survey data, for those Bird Conservation Regions within provinces that had sufficient data to estimate trends for Bicknell's Thrush. Blue shading shows 95% credible intervals for the GAM (generalized additive model) trend (A. Smith unpubl. data).

Summary

Considering the limitations of relatively sparse BBS trend data for Bicknell's Thrush, and possible sampling biases inherent in databases such as eBird, it is useful to take a weight-of-evidence approach to evaluating population trends. Two estimates of the rate of decline over the past 10-year period, derived from BBS data, are 34.2% and 53.7%, depending on the analytical method used. eBird observations (eBird 2021; Figure 10) and Mountain Birdwatch (e.g., Kouwenberg 2020; Torrenta 2021b) records indicate recent declines of similar magnitude (eBird: ca. 39%), with several of the most important breeding areas in Nova Scotia having been abandoned during the past 10-year period. Canadian BBS data indicate a 79% probability that the population declined by at least 30% over the period 2009–2019 and a 55% probability that it decreased by at least 50% over that same period, although this is based on few data (Smith *et al.* 2020; Figure 8). Atlas results show that Bicknell's Thrush has now disappeared from some coastal sites in Quebec (Robert *et al.* 2019) and from coastal islands of southwestern Nova Scotia and the Bay of Fundy (Stewart *et al.* 2015), and the species no longer occurs in former strongholds on Cape Breton Island (Kouwenberg 2020), confirming that breeding range and numbers continue to contract.

Population Fragmentation

Although the montane breeding habitat used by Bicknell's Thrush is naturally quite fragmented (Figure 2), the species appears to be well-adapted to bridging gaps among groups of breeding birds through its relatively extensive natal dispersal movements (Studds *et al.* 2012; Townsend *et al.* 2020; see **Movement, Dispersal, and Migration**).

Rescue Effect

There is evidence for extensive movement and interchange among Canadian and U.S. populations, based on an analysis of feather deuterium ratios (Studds *et al*. 2012), which provided evidence for connections between the Gaspé Peninsula and northern New England through natal dispersal.

Long-term U.S. BBS trends (1970–2019) show an ongoing annual rate of decline of 4.06% (95% CI: -8.83, -0.34), similar to the Canadian annual rate of decline over the same period. Short-term U.S. BBS declines (-7.19%, 95% CI: -20.91, 2.55) are also similar to rates calculated for Canadian populations. Recent trends (2011–2019) from the Mountain Birdwatch Program (Hill 2020) indicate an annual rate of decline of -2.41% for all states combined, with a relatively tight 95% CI (-4.44, -0.45). Annual rates of decline estimated by the Mountain Birdwatch Program from 2011 to 2019 for individual states were highest in New York (-6.35) and New Hampshire (-5.00), whereas Vermont showed a slightly positive rate of change (1.61). Potential source populations in the northeastern United States are declining, with the possible exception of Vermont (Hill 2020). In addition, although there appear to be relatively extensive areas of potential breeding habitat available in some parts of Quebec (e.g., Aubry *et al.* 2018), the extent and quality of breeding habitat in Canada continue to decline due to forest management activities. The effects of climate change are likely also impacting habitat quality (see **Habitat Trends**). As a consequence, the probability of rescue from the United States is considered to be very low.

THREATS

Current and Future Threats

Bicknell's Thrush is vulnerable to the cumulative impact of various threats. These are categorized below and in Appendix 1, following the IUCN-CMP (International Union for the Conservation of Nature – Conservation Measures Partnership) unified threats classification system (based on Salafsky *et al*. 2008). The evaluation assesses impacts for each of 11 main categories of threats and their subcategories, based on the scope (proportion of population exposed to the threat over the next 10-year period), severity (predicted population decline among those exposed to the threat during the next 10 years or three generations, whichever is longer), and timing of each threat. The overall threat impact is calculated by taking into account the separate impacts of all threat categories and can be adjusted by the species experts participating in the evaluation.

For Bicknell's Thrush, the overall threat impact is considered to be High-Medium, corresponding to an anticipated further decline of between 3% and 70% over the next 10 years (see Appendix 1 for details). Threats with an impact score greater than negligible are discussed below in order of decreasing severity of impact (greatest to least), ending with those for which scope or severity is unknown.

<u>IUCN 5. Biological resource use (Medium-Low impact):</u>

Description of threat:

Timber harvesting and forest management (IUCN 5.3) alter and may sometimes help to maintain breeding habitat across much of the Canadian breeding range (ECCC 2020). Bicknell's Thrush nests in stands dominated by dense Balsam Fir regeneration (Rompré *et al*. 1999), especially in the 5–10 cm dbh class (Nixon *et al*. 2001; Chisholm and Leonard 2008). Such stands are generally managed with precommercial thinning, often undertaken during the breeding season (ECCC 2020). Precommercial thinning reduces stem density in the densest regenerating conifer stands and has been shown to cause a three-fold decrease in abundance of breeding Bicknell's Thrush (Chisholm and Leonard 2008). These authors reported that Bicknell's Thrush abundance was highest in unthinned, clear-cut stands aged 11–13 years, about the age at which they are normally subject to precommercial thinning. At the stand level, Bicknell's Thrush abundance was positively correlated with the area of unthinned patches (Chisholm and Leonard 2008), and individual home ranges include greater proportions of unthinned stands than expected by random (Aubry et al. 2011). Poor natural regeneration following precommercial thinning may promote the use of plantation silviculture, which favours the growth of spruce (*Picea* spp.). Spruce plantations occur at elevations occupied by Bicknell's Thrush in both New Brunswick (Hadley pers. comm. 2021) and Quebec (Aubry pers. comm. 2021). Timber harvesting for charcoal production (IUCN 5.3) impacts habitat on the wintering grounds (Lloyd and MacFarlane 2017). No information is available on the incidence of shooting or trapping of Bicknell's Thrush (IUCN 5.1), which is thought to be rare.

Scope:

Large-restricted. Approximately 90% of Bicknell's Thrush breeding habitat in Canada is located on lands managed for forest harvesting (ECCC 2020), and precommercial thinning is widely used in the Highlands ecoregion of New Brunswick (Diamond pers. comm. 2021) and in some parts of the Quebec range (Aubry *et al.* 2011, 2018). Charcoal production is a relatively localized phenomenon on the wintering grounds (Lloyd and McFarland 2017).

Severity:

Moderate. Bicknell's Thrush tends to avoid recently thinned stands within its home range (Aubry *et al.* 2011) or at the stand level (Chisholm and Leonard 2008; Aubry *et al.* 2016). Thinning treatments may also cause direct mortality through the destruction of nests or post-fledging habitat (ECCC 2020). However, Bicknell's Thrush can persist at lower densities in landscapes where thinned stands are interspersed with dense Balsam Fir regeneration (Chisholm and Leonard 2008; Aubry *et al.* 2011). It can also persist in areas disturbed by charcoal production, as long as this practice is restricted to small patches (Lloyd and McFarland 2017).

<u>IUCN 8. Invasive and other problematic species and genes (Medium-Low impact):</u>

Description of threat:

Introduced mammalian predators (IUCN 8.1), including Black and Norway Rats (Townsend *et al.* 2009), domestic cat (*Felis catus*), and mongoose (family Herpestidae; Lloyd and McFarland 2017) may cause direct mortality of Bicknell's Thrush on its wintering grounds. Feral pig (*Sus scrofa*) may also cause habitat degradation on the wintering grounds as they disturb understorey vegetation (Lloyd and McFarland 2017).

Poor natural regeneration following precommercial thinning may promote the use of spruce plantations in forest management. The resulting replacement of fir-dominated stands by Black Spruce plantations may result in higher densities of cone-hoarding Red Squirrels (IUCN 8.2) as spruce cones contain seeds for several years, whereas fir cones rarely persist from year to year (Burns and Honkala 1990; McDermott *et al*. 2020). Spruce plantations provide a more stable food source for squirrels, and higher squirrel populations may increase predation on Bicknell's Thrush nests.

Severe outbreaks of Spruce Budworm (IUCN 8.2), such as those occurring on the north shore of the St. Lawrence River and the Gaspé Peninsula in Quebec (Figure 7), may kill Balsam Fir over large areas (see **Limiting Factors**). The intensity and extent of outbreaks are influenced by forest management practices that favour even-aged, Balsam Fir-dominated stands, making them susceptible to outbreaks that may be both more extensive and more intense than those occurring in naturally heterogeneous forest landscapes (Robert *et al*. 2018). The current outbreak is affecting large portions of Bicknell's Thrush breeding range (Figure 7), and in the most severely-affected stands, regenerating Balsam Fir is often killed (Poulin pers. comm. 2021).

In recent years, Moose (*Alces americanus*) was overabundant in northern Cape Breton island and has caused extensive habitat degradation, locally replacing dense Balsam Fir regeneration by grassy clearings (Smith *et al*. 2010).

Scope:

Pervasive. The scope of impacts of introduced mammalian predators (UCN 8.1) was considered pervasive as two rat species pose a threat in all wintering habitat used by Bicknell's Thrush on Hispaniola (Rimmer pers. comm. 2021). The scope related to the effects of Spruce Budworm outbreaks (IUCN 8.2) was also considered pervasive as it affects extensive areas of breeding habitat and is likely to continue for many years (Figure 7). Impacts of spruce plantations on Red Squirrel populations are expected to be more localized, as are those of Moose in the Cape Breton Highlands.

Severity:

Moderate-slight. Overall severity of impacts of introduced mammalian predators (IUCN 8.1) on Bicknell's Thrush is considered slight. Impacts of increased Red Squirrel populations may be regionally important as a function of the area planted with spruce. Short- and long-term effects of Spruce Budworm (IUCN 8.2) on habitat quality, occurrence, or productivity have not been well documented but are anticipated to be locally significant, as is the case for habitat degradation by Moose, hence a severity of moderate-slight.

<u>IUCN 1. Residential and commercial development (Low impact):</u>

Description of threat:

Bicknell's Thrush generally occurs in habitats far from areas of residential and commercial development. However, mortality by collision with buildings has been documented during migration, mainly in urban areas (IUCN 1.1; Georgia Museum of Natural History in Townsend *et al*. 2020), and may also occur in commercial or industrial areas (IUCN 1.2).

Scope:

Small. A relatively small proportion of birds is likely to be impacted, and some individuals may be at risk of collisions with buildings as they pass through dense urban developments and resorts when migrating along the Atlantic coast of the United States (Bégin-Marchand *et al.* 2020). The development of backcountry skiing (e.g., at Massif du Sud and in the Chic-Choc mountain range; IUCN 1.3) causes some direct habitat loss, and trail development can remove as much as 70% of forest cover (Lemaître pers. comm. 2021).

Severity:

Slight. It is likely that most Bicknell's Thrush that strike buildings are killed instantly or die shortly thereafter, but the proportion of the population affected was estimated to be much less than 10%. The development of backcountry skiing trails may affect relatively limited areas, mainly in Quebec's Gaspé Peninsula.

<u>IUCN 2. Agriculture and aquaculture (Low impact):</u>

Description of threat:

Forest loss and degradation as a result of shifting (slash-and-burn) and industrial agriculture (IUCN 2.1) can be a considerable threat on the wintering grounds, especially for female Bicknell's Thrush, whose habitat in rainforests at lower elevations is particularly vulnerable to the expansion of farming (McFarland *et al.* 2018).

Scope:

Restricted. Impacts are concentrated in limited portions of the wintering grounds.

Severity:

Moderate. Severity is considered moderate owing to limitations on the availability of alternate habitat. However, current negative habitat effects on the wintering grounds may decrease as forest is regenerating on abandoned agricultural land used in winter (Townsend *et al.* 2020).

<u>IUCN 3. Energy production and mining (Low impact):</u>

Description of threat:

The primary threat in this category is the effect of wind energy development (IUCN 3.3) in breeding areas on high-elevation montane ridges, which may cause habitat loss through clearing for turbine pads and access roads, with potential for some mortality through direct strikes. Effects of ongoing wind power generation are thought to be much lower.

Scope:

Restricted-small. Relatively small areas of Bicknell's Thrush habitat are directly affected by wind energy development, and Lemaître and Lamarre (2020) reported that Bicknell's Thrush probability of occurrence did not increase with distance from turbine pads. However, the scope of this threat may increase as areas with potential for wind energy development often overlap with Bicknell's Thrush habitat (Lloyd and McFarland 2017; Aubry pers. comm. 2020) and new wind energy projects are being developed in Quebec and the Maritime provinces.

Severity:

Slight. The precise duration of construction effects on occurrence is unknown but likely to be short, although this conclusion is based on point counts conducted during and after the construction of a single wind farm (Lemaître and Lamarre 2020).

IUCN 7. Natural system modifications (Unknown impact):

Description of threat:

The frequency and intensity of wildfires (IUCN 7.1) were modelled by Cadieux *et al*. (2019) under different climate change scenarios. Bicknell's Thrush habitat is sensitive to effects of wildfire as fire tends to favour those tree species that are better adapted to regenerate after burning than Balsam Fir, such as Black Spruce and Jack Pine (*Pinus banksiana*) (Burns and Honkala 1990).

Scope:

Unknown. The analysis conducted by Cadieux *et al.* (2019) did not indicate the relative contribution of wildfire to projected Bicknell's Thrush habitat reduction as a result of climate change.

Severity:

Moderate-slight.

IUCN 9. Pollution (Unknown impact):

Description of threat:

Atmospheric deposition of mercury and other airborne pollutants, such as lead, nitrogen, and sulphur oxides, may have direct effects on health of Bicknell's Thrush, as well as indirect effects through habitat degradation as a result of soil acidification (IUCN 9.5). Methylation and biomagnification of mercury is known to take place in high-elevation forests of the northeastern United States, and methyl mercury is neurotoxic (Rimmer *et al*. 2005). Although lead concentrations in soils are decreasing in New England, acidity of precipitation in northeastern North America has not decreased (Townsend *et al*. 2020 and references therein). In the Adirondack Mountains, *Catharus* thrushes (including Bicknell's) had some of the highest blood concentrations of mercury recorded among 15 songbird species (Sauer *et al*. 2020). Apart from one individual sampled on the wintering grounds (Townsend *et al*. 2013), levels of mercury in blood samples of Bicknell's Thrush (0.05–0.180 μg/g; Rimmer *et al.* 2019; Sauer *et al*. 2020) were below concentrations known to negatively impact physiology or reproduction in other songbird species (Whitney and Cristol 2017). In Canada, mercury deposition remained relatively stable in coastal ecosystems between 1972 and 2008 (Burgess *et al.* 2013). Feather mercury concentrations in songbirds show a longitudinal gradient in Canada, reaching their highest levels in eastern Canada (Ma *et al*. 2021).

Spraying of the bacterial insecticide Btk (*Bacillus thuringiensis* var. *kurstaki*) to control Spruce Budworm and Hemlock Looper (*Lambdina fiscellaria*) may reduce food abundance through its effects on many Lepidopteran larvae (IUCN 7.3). Nonetheless, the literature on the effects of Btk spraying on songbirds themselves is inconclusive. Sopuck *et al.* (2000) reported no significant effects on the relative abundance of nearly all songbird species monitored, whereas Awkerman *et al*. (2011) found that adults altered their nest provisioning behaviour in Btk plots, resulting in lower nestling mass.

Spraying of glyphosate is rare in the New Brunswick stronghold of Bicknell's Thrush (Highlands ecoregion) because spruce plantations are not widely used at those elevations, and hardwood regeneration is not as vigorous as it is at lower elevations.

Scope:

Pervasive. Mercury deposition likely occurs throughout the Canadian breeding range of Bicknell's Thrush, with concentrations increasing with elevation. Mercury has also been detected in blood samples of individuals wintering in cloud forests of Hispaniola, the latter exhibiting blood Hg concentrations two to three times higher than those reported from the breeding grounds (Townsend *et al*. 2013). Large areas of eastern Canada are affected by Spruce Budworm infestations (Figure 7), many of which are sprayed with Btk, likely including Bicknell's Thrush breeding habitat.

Severity:

Unknown. Long-term effects of reported blood mercury levels on the health of Bicknell's Thrush are uncertain, although modelling suggests that songbird reproduction can be impaired at higher blood mercury concentrations than recorded in this species (≥0.7 micrograms/g; Jackson *et al*. 2011).

<u>IUCN 11. Climate change and severe weather (Unknown impact):</u>

Description of threat:

Changes in the extent and quality of breeding habitat are predicted by climate change modelling, especially through reductions in the extent of Balsam Fir stands at high elevations or on plateaus as a result of warming temperatures (Rodenhouse *et al.* 2008; Cadieux *et al.* 2019). Models suggest that Bicknell's Thrush habitat will be lost through changes in forest composition that favour temperate deciduous tree species (see **Habitat Trends**; Cadieux *et al*. 2019). Balsam Fir is expected to suffer from warmer and drier conditions, whereas temperate deciduous trees are expected to expand their distribution northward (or upward in elevation; Savage and Vellend 2014) under those climatic conditions. Climate-driven 50% habitat loss is expected to occur earlier (ca. 2038) in the northeastern United States (Rodenhouse *et al*. 2008) than in Canada (ca. 2100; Cadieux *et al*. 2019). The frequency of severe weather events, especially fall tropical storms over the Caribbean, is predicted to increase with climate change, potentially reducing the survival rate of individuals during migration or on the wintering grounds, or indirectly through habitat degradation. Climate change may also disrupt the biennial masting cycle of Balsam Fir and lead to more regular incursions of Red Squirrel into Bicknell's Thrush habitat and, therefore, maintain consistently high nest predation rates (Rimmer pers. comm. 2021). A drying trend already occurring in wintering habitat on Hispaniola may have severe negative effects on fitness and possibly survival, as suggested through an upgrade experiment on another species of Neotropical migrant (Studds and Marra 2005).

Scope:

Pervasive. Effects of changing climate are anticipated to affect the entire Bicknell's Thrush breeding range and most of its wintering range.

Severity:

Unknown. The severity of predicted habitat changes is anticipated to be quite high and the frequency of severe weather events is expected to increase, with most impacts likely to occur beyond 10 years.

Habitat Trends

Approximately 90% of Bicknell's Thrush habitat in Canada is located on lands managed for forest harvesting (ECCC 2020). Precommercial thinning has been shown to have negative effects on the occurrence and abundance of the species (e.g., Chisholm and Leonard 2008; Aubry *et al*. 2016, 2018). Hence, intensive forest management influences habitat quality, but no study has provided a before-after test of such effects or investigated the potential interactions between specific timber harvesting regimes and changing climate (Lloyd and McFarland 2017). Cadieux *et al.* (2019) simulated such interactions and concluded that clear-cutting without precommercial thinning could partly offset the loss of breeding habitat.

The combined, direct and indirect effects of airborne pollutants (including toxic heavy metals such as lead and mercury), atmospheric deposition of acidic ions (NO_x, SO_x), and increased frequency of winter freezing injury of spruce have been linked to the widespread dieback of Red Spruce at high elevations in the northeastern United States (DeHayes *et al.* 1999). Effects of these factors on Balsam Fir are not as clear. Lead concentrations on the forest floor are decreasing, but there is no indication of a reduction in the acidity of precipitation in spite of the reduction in emissions (US EPA 2014; Lawrence *et al*. 2015).

Cadieux *et al.* (2019) modelled climate change effects in the Boreal Shield and Atlantic Maritime ecozones of Quebec and New Brunswick. They predicted the loss of over 50% of the current Bicknell's Thrush habitat by 2100 under the worst climate change scenario, as a consequence of warmer and drier conditions favouring deciduous species over Balsam Fir. Iverson *et al.* (2008) predicted that Balsam Fir and Red Spruce would be among the tree species whose range would contract in the eastern United States as a result of anticipated climate change scenarios. Rodenhouse *et al.* (2008) further predicted that a 1°C increase in temperature would result in the loss of more than half of the habitat of tree species currently occupying high elevations (e.g., Balsam Fir, Red Spruce, White Birch).

Of major concern is the drying trend that is already affecting wintering habitat on Hispaniola with unknown but presumed negative effects, especially at lower elevations, where female Bicknell's Thrushes predominate (Townsend *et al*. 2012).

Other sources of habitat change include loss of potential breeding habitat through wind energy development and construction of telecommunication towers on mountaintops (Townsend *et al.* 2020), as well as browsing by Moose in Cape Breton Highlands (see **Threats**). Wintering habitat continues to be lost and degraded through industrial and shifting (slash-and-burn) agriculture, although past habitat trends may be reversed as forest regenerates on abandoned agricultural land (Lloyd and McFarland 2017).

Number of Threat-based Locations

Bicknell's Thrush occupies naturally fragmented breeding habitat, largely restricted to high elevations and plateaus, which is connected through natal dispersal movements (see **Movement, Dispersal, and Migration**). Most of the main threats are unlikely to affect all occurrences at the same time, except for airborne pollutants and climate change, which are anticipated to occur gradually over the next several decades (Rodenhouse *et al*. 2008; Cadieux *et al*. 2019). Timber harvesting and forest management (IUCN 5.3) are taken as the most serious plausible threat affecting Bicknell's Thrush. Forestry-related impacts affect relatively small areas over the period considered and shift across the landscape over time. Each such area is considered to be a different location, and the resulting number of locations is unknown but is much greater than 10.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Bicknell's Thrush was listed as Threatened in Canada under Schedule 1 of the *Species at Risk Act* in 2012, and the species and its nests are protected in Canada under the *Migratory Birds Convention Act* (1994). Bicknell's Thrush is considered Threatened in New Brunswick (2013) and Endangered (2013) in Nova Scotia (Table 4). In Quebec, it is listed as Vulnerable under the *Act respecting threatened or vulnerable species* (CQLR, c E-12.01) and is afforded protection under the *Act respecting the conservation and development of wildlife* (CQLR, c. C-61.1).

In the United States, Bicknell's Thrush is nationally listed as Apparently Secure (US FWS 2017) and, therefore, it is not protected under the *Endangered Species Act*. At the state level, it is designated as Special Concern in New York, Vermont, and Maine, as Special Concern (Category B) in New Hampshire, and presumed Extirpated in Massachusetts (Table 4).

Table 4. Conservation status of Bicknell's Thrush in Canada and the United States, from the General Status of Wild Species in Canada (Wild Species 2015), Birdlife International (2021), and NatureServe (2021).

Jurisdiction	NatureServe[1]	Status[2]
Global	G4	Apparently Secure (NatureServe 2021)
Canada	N2B,N2M	Threatened (6/20/2012)
Quebec	S2B	Vulnerable (9/2009)
New Brunswick	S2B	Threatened (2013)
Prince Edward Island	SHB,SHM	
Nova Scotia	S1B	Endangered (2013)
United States	N4B	Not listed
Maine	S3B	Special Concern
Massachusetts	SXB	Presumed extirpated
New Hampshire	S2S3B	Species of Concern Category B
New Jersey	S3N	
New York	S2S3B	Special Concern
Vermont	S2B	Special Concern

[1] Status levels: G = Global; N (at start of rank) = National; S = Subnational; B = Breeding; N (at end of rank) = Non-breeding. 1 = Critically Imperilled; 2 = Imperilled; 3 = Vulnerable; 4 = Apparently Secure; 5 = Secure; NA = Not Applicable; NR = Not Ranked; U = Unrankable (due to lack of information or conflicting information); ? Inexact numeric rank

[2] Listing as Endangered, Threatened, Special Concern, or equivalent designations, at jurisdictional level.

Non-Legal Status and Ranks

The IUCN Red List classifies Bicknell's Thrush as globally Vulnerable (BirdLife International 2021). NatureServe (2021) ranks the species as: Apparently Secure (G4); N2B,N2M in Canada; N4B in the United State; S1B in Nova Scotia; S2B in New Brunswick, Quebec, and Vermont; S2S3B in New Hampshire and New York; S3B in Maine; and S3N in New Jersey (NatureServe 2021).

Bicknell's Thrush is on the Red Watch List of Partners in Flight owing to its high degree of habitat specialization and its limited range in both summer and winter (Partners in Flight 2021) and is identified by the US Fish and Wildlife Service as a Bird Species of National Concern (Lloyd and McFarland 2017).

Land Tenure and Ownership

Bicknell's Thrush has been detected in eight national or provincial parks in Quebec, one in New Brunswick, and one in Nova Scotia since 2010 (Table 5), as well as in nearby Baxter State Park in Maine. It has also been reported in several Important Bird Areas (IBAs; some of which are in national or provincial parks), including Mont Gosford, Mont Mégantic, Charlevoix, Île Bonaventure, Péninsule de Forillon, and Île Brion IBAs in Quebec; Nepisiguit Highlands and Grand Manan Archipelago IBAs in New Brunswick; and Cape

Breton Highlands National Park, Cape North and Money Point, St. Paul Island, and Scatarie Island IBAs in Nova Scotia. However, the species has not been reported from Île Brion IBA since 1989, from Grand Manan Archipelago IBA since the second breeding bird atlas (Stewart *et al.* 2015), nor from St. Paul Island IBA since 2010. The latest observation from Scatarie Island IBA is a "probable" detection based on ARU recordings (Achenbach unpubl. data). The only record from Anticosti Island IBA, Quebec, is now suspected to belong to a Gray-cheeked Thrush (ÉPOQ data, J. Larivée and Regroupement QuébecOiseaux). Finally, Bicknell's Thrush has been reported at several sites within land set aside in the Chic-Choc mountain range of Quebec for the creation of a future protected area (Jean-St-Laurent pers. comm. 2021).

Table 5. Protected areas in which Bicknell's Thrush has been reported at least once since 2010.

Name	Province or State	Potential habitat (ha)[1]	Latest detection (yr)	Information source
Parc national du Mont-Tremblant	Quebec	1949	2020	eBird 2021
Parc national de la Jacques-Cartier	Quebec	50,894	2016	B. Dubeau, unpubl. data 2016
Parc national du Mont-Mégantic	Quebec	2280	2020	eBird 2021
Parc national de la Gaspésie	Quebec	57,550	2019	eBird 2021
Parc national des Hautes-Gorges de-la-Rivière-Malbaie	Quebec	9294	2012	eBird 2021
Parc national des Grands-Jardins	Quebec	30,846	2017	eBird 2021
Parc national des Monts-Valin	Quebec	7864	2020	eBird 2021
Parc national de l'Île-Bonaventure-et-du-Rocher-Percé	Quebec	416	2019	eBird 2021
Parc national du Canada de Forillon / Forillon National Park	Quebec	4927	2004[1]	Plouffe Leboeuf pers. comm. 2022
Réserve écologique de Tantaré	Quebec	196	NA	COSEWIC 2009
Réserve écologique Claude-Mélançon	Quebec	447	2020	eBird 2021
Propriété Bélanger (Mont Sutton)	Quebec	40	2020	eBird 2021
Mount Carleton Provincial Park	New Brunswick	3226	2016	eBird 2021
Fundy National Park	New Brunswick	NA	2009[1]	Wilson pers. comm. 2021
Cape Breton Highlands National Park	Nova Scotia	61,500	2017	eBird 2021
Scatarie Island	Nova Scotia	NA	2019[2]	L. Achenbach, unpubl. data
Margaree River Wilderness Area	Nova Scotia	2898	NA	COSEWIC 2009
Baxter State Park	Maine, United States	NA	2020	eBird 2021
TOTAL		234,031		

[1] Forillon and Fundy National Parks are shown even though the latest confirmed sightings were made prior to 2010 on the basis of post-2010, unconfirmed eBird records.

[2]A single detection deemed "probable" based on an ARU recording.

Recovery Activities

The International Bicknell's Thrush Conservation Group published an initial Action Plan in 2010 (IBTCG 2010) and a revised version in 2017 (Lloyd and McFarland 2017). Models have been developed to estimate habitat quality in Quebec (Broeckaert 2011), and Critical Habitat has been partially identified on the basis of the best available knowledge (ECCC 2020). Priority sites have been identified for conservation (Julien *et al.* 2014) in Quebec and recommendations formulated to plan habitat management and protection (Bussière and Julien 2012a,b). The Gouvernement du Québec (2014) identified high elevation and coastal Balsam Fir stands with high potential to host Bicknell's Thrush and sites where its presence has been confirmed. It imposed a maximum of 33% habitat disturbance by forest management in areas characterized as having high potential, with no disturbance permitted in areas where Bicknell's Thrush has been confirmed.

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Authorities contacted

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Whittam, Becky. Head – Terrestrial and Marine Conservation, Canadian Wildlife Service, Environment and Climate Change Canada, Sackville, New Brunswick.

INFORMATION SOURCES

Able, K.P., and B.R. Noon. 1976. Avian community structure along elevational gradients in the Northeastern United States. Oecologia 26:275-294.

Achenbach, L., unpublished data 2019. Scatarie Report 2019. Birds Canada, Sackville, New Brunswick.

A.O.U. 1995. Fortieth supplement to the American Ornithologists' Union checklist of North American birds. Auk 112:819-830.

Artuso, C., pers. comm. 2022. *Email correspondence with M.-A. Villard*. January 2022. Biologist, Canadian Wildlife Service, Environment and Climate Change Canada, Ottawa, Canada.

Askanas, H. 2012. Does mating system affect the physiological stress of provisioning birds? A comparative study of polygynandrous Bicknell's thrush (*Catharus bicknelli*) and socially monogamous Swainson's thrush (*Catharus ustulatus*) breeding sympatrically. M.Sc. thesis, University of New Brunswick, Fredericton, New Brunswick.

Aubry, Y., pers. comm. 2020. *Email correspondence with M.-A. Villard*. December 2020. Biologist, Canadian Wildlife Service, Environment and Climate Change Canada, Quebec City, Quebec.

Aubry, Y., pers. comm. 2021. *Telephone conversation with M.-A. Villard*. February 2021. Biologist, Canadian Wildlife Service, Environment and Climate Change Canada, Quebec City, Quebec.

Aubry, Y., unpublished data 2021. Biologist, Canadian Wildlife Service, Environment and Climate Change Canada, Quebec City, Quebec.

Aubry, Y., A. Desrochers, and G. Seutin. 2011. Response of Bicknell's Thrush (*Catharus bicknelli*) to boreal silviculture and forest stand edges: a radio-tracking study. Canadian Journal of Zoology 89:474-482.

Aubry, Y., A. Desrochers, and G. Seutin. 2016. Regional patterns of habitat use by a threatened forest bird, the Bicknell's Thrush (*Catharus bicknelli*), in Quebec. Canadian Journal of Zoology 94:301-309.

Aubry, Y., A. Desrochers, and G. Seutin. 2018. Bicknell's Thrush (*Catharus bicknelli*) habitat occupancy in Québec's Laurentian Highlands. Avian Conservation and Ecology 13:8. https://doi.org/10.5751/ACE-01226-130208

Aubry, Y., and F. Shaffer. 2019. Grive de Bicknell (*Catharus bicknelli*). Pp. 428-429 *in* M. Robert, M.-H. Hachey, D. Lepage, A.R. Couturier (eds). Deuxième atlas des oiseaux nicheurs du Québec méridional. Environment and Climate Change Canada, Regroupement QuébecOiseaux, and Bird Studies Canada. Montreal, Quebec. 694 pp.

Awkerman, J.A., M.R. Marshall, A.B. Williams, G.A. Gale, R.J. Cooper, and S. Raimondo. 2011. Assessment of indirect pesticide effects on worm-eating warbler populations in a managed forest ecosystem. Environmental Toxicology and Chemistry 30:1843-1851.

Ball, M. 2000. Vocal behaviour of Bicknell's Thrush (*Catharus bicknelli*). M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

Bégin-Marchand, C., A. Desrochers, J. Tremblay, and P. Côté. 2020. Comparing fall migration of three *Catharus* species using a radio-telemetry network. Animal Migration 7:1-9.

Bird, J.P., R. Martin, H.R. Akçakaya, J. Gilroy, I.J. Burfield, S.T. Garnett, A. Symes, J. Taylor, C.H. Şekercioğlu, and S.H.M. Butchart. 2020. Generation lengths of the world's birds and their implications for extinction risk. Conservation Biology 34:1252–1261. https://doi.org/10.1111/cobi.13486

BirdLife International. 2021. *Catharus bicknelli*. The IUCN Red List of Threatened Species 2020. Website: http://datazone.birdlife.org/species/factsheet/bicknells-thrush-catharus-bicknelli [accessed 31 July 2021].

Broeckaert, M. 2011. Réalisation cartographique de la potentialité de l'habitat de la Grive de Bicknell par le biais d'une analyse factorielle de la niche écologique, au Québec, en 2011. Regroupement QuébecOiseaux, Montreal, Quebec. 38 pp.

Burgess, N.M., A.L. Bond, C.E. Hebert, E. Neugebauer, and L. Champoux. 2013. Mercury trends in herring gull (*Larus argentatus*) eggs from Atlantic Canada, 1972-2008: temporal change or dietary shift? Environmental Pollution 172:216-222.

Burns, R.M., and B.H. Honkala. 1990. Silvics of North America. Volume I. Conifers. U.S. Department of Agriculture. Forest Service. Website: https://srs.fs.usda.gov/pubs/misc/ag_654/table_of_contents.htm [accessed December 2020].

Bussière, F., and M.-F. Julien. 2012a. Planifier l'aménagement du territoire pour la protection de l'habitat de la Grive de Bicknell sur les terres publiques provinciales. Portrait de la situation et recommandations pour les régions de la Gaspésie et du Bas-Saint-Laurent. Regroupement QuébecOiseaux, Montreal, Quebec, 50 pp.

Bussière, F., and M.-F. Julien. 2012b. Planifier l'aménagement du territoire pour la protection de l'habitat de la Grive de Bicknell sur les terres publiques provinciales. Portrait de la situation et recommandations pour la région de la Capitale-Nationale. Regroupement QuébecOiseaux, Montreal, Quebec. 49 pp.

Cadieux, P., Y. Boulanger, D. Cyr, A.R. Taylor, D.T. Price, and J.A. Tremblay. 2019. Spatially explicit climate change projections for the recovery planning of threatened species: the Bicknell's Thrush (*Catharus bicknelli*) as a case study. Global Ecology and Conservation 17:e00530.

Campbell, G.B., and B. Stewart. 2012. High elevation landbird program – 10-year report. Bird Studies Canada, Atlantic Region, Sackville, New Brunswick. 19 pp.

Chisholm, S.E., and M.L. Leonard. 2008. Effect of forest management on a rare habitat specialist, the Bicknell's Thrush (*Catharus bicknelli*). Canadian Journal of Zoology 86:217-223.

Connolly, V., G. Seutin, J.-P.L. Savard, and G. Rompré. 2002. Habitat use by the Bicknell's Thrush in the Estrie region, Quebec. The Wilson Bulletin 114:333-341.

COSEWIC. 2009. COSEWIC assessment and status report on the Bicknell's Thrush *Catharus bicknelli* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. Vii + 44 pp. Website: https://species-registry.canada.ca/index-en.html#/documents/1971 [accessed 20 April 2020].

DeHayes, D.H., P.G. Schaberg, G.J. Hawley, and G.R. Strimbeck. 1999. Acid rain impacts on calcium nutrition and forest health: alteration of membrane-associated calcium leads to membrane destabilization and foliar injury in red spruce. BioScience 49:789-800.

DeLuca, W.V., and D.I. King. 2014. Influence of hiking trails on montane birds. Journal of Wildlife Management 78 :494-502.

Desrochers, A., unpublished data 2020. Professor, Département des sciences du bois et de la forêt, Université Laval, Quebec City, Quebec.

Desrochers, A., unpublished. data 2021. Professor, Département des sciences du bois et de la forêt, Université Laval. Quebec City, Quebec.

Desrochers, A., Y. Aubry, and J. Tremblay. 2017. Sélection de l'habitat de la Grive de Bicknell durant la période pré-migratoire. Rapport final 2015-17. Submitted to Fondation de la faune du Québec. Quebec City, Quebec.

Diamond, A.W., pers. comm. 2021. *Email correspondence with M.-A. Villard*. February 2021. Professor *emeritus*, Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, New Brunswick.

Dubeau, B., unpublished data 2016. Director, Conservation and Education Service. Parc national de la Jacques-Cartier, Stoneham-et-Tewksbury, Quebec.

eBird. 2021. eBird: An online database of bird distribution and abundance. eBird, Cornell Lab of Ornithology, Ithaca, New York. Website: http://www.ebird.org [accessed January 2021].

ECCC. 2020. Recovery strategy for the Bicknell's Thrush (*Catharus bicknelli*) in Canada. Species at Risk Recovery Strategy Series, Environment and Climate Change Canada, Ottawa, Ontario. 96 pp.

ÉPOQ. 2021. Étude des populations d'oiseaux du Québec. Website: https://www.oiseauxqc.org/epoq.jsp [accessed January 2021].

Erskine, A.J. 1992. Atlas of Breeding Birds of the Maritime Provinces. Nimbus Publications and Nova Scotia Museum, Halifax, Nova Scotia. 270 pp.

Fitzgerald, A.M. 2017. Division within the North American boreal forest: Ecological niche divergence between the Bicknell's Thrush (*Catharus bicknelli*) and Gray-cheeked Thrush (*C. minimus*). Ecology and Evolution 7:5285-5295. https://doi.org/10.1002/ece3.3080

Fitzgerald, A.M., D.M. Whitaker, J. Ralston, J.J. Kirchman, and I.G. Warkentin. 2017. Taxonomy and distribution of the imperilled Newfoundland Gray-cheeked Thrush, *Catharus minimus minimus*. Avian Conservation and Ecology 12(1):10. https://doi.org/10.5751/ACE-00976-120110

Freeman, B.G., and G. Montgomery. 2016. Interspecific aggression by the Swainson's Thrush (*Catharus ustulatus*) may limit the distribution of the threatened Bicknell's Thrush (*Catharus bicknelli*) in the Adirondack Mountains. Condor 118:169-178.

Frey, S.J.K., C.C. Rimmer, K.P. McFarland, and S. Menu. 2008. Identification and sex determination of Bicknell's Thrushes using morphometric data. Journal of Field Ornithology 79:408-420.

Gauthier, Y., pers. comm. 2021. *Email correspondence with M.-A. Villard.* January 2021. Amateur ornithologist. Montreal, Quebec.

Goetz, J.E., K.P. McFarland, and C.C. Rimmer. 2003. Multiple paternity and multiple male feeders in Bicknell's Thrush (*Catharus bicknelli*). Auk 120 :1044-1053.

Gouvernement du Québec. 2014. Mesure de protection de la Grive de Bicknell à l'égard des activités d'aménagement forestier. Sous-comité Faune de l'Entente administrative. Quebec City, Quebec. 26 p. Website: https://mffp.gouv.qc.ca/documents/forets/amenagement/Mesure-protection-grive-Bicknell.pdf. [accessed 20 April 2020].

Hadley, A., pers. comm. 2021. *COSEWIC threat assessment call.* September 2021. Biologist. Department of Natural Resources and Energy Development, Government of New Brunswick, Fredericton, New Brunswick.

Halley, M.R., C.M. Heckscher, and V. Kalavacharia. 2016. Multi-generational kinship, multiple mating, and flexible modes of parental care in a breeding population of the Veery (*Catharus fuscescens*), a trans-hemispheric migratory songbird. PLOS ONE 11(6):e0157051.

Hennigar, C.R., D.A. MacLean, D.T. Quiring, and J.A. Kershaw. 2008. Differences in spruce budworm defoliation among balsam fir and white, red, and black spruce. Forest Science 54:158-166. https://academic.oup.com/forestscience/article/54/2/158/4604104

Hill, J.M. 2020. The State of the Mountain Birds Report: 2020. Vermont Center for Ecostudies, White River Junction, Vermont. Website: https://mountainbirds.vtecostudies.org [accessed 13 January 2021].

Hill, J.M., unpublished data 2021. Quantitative Ecologist. Vermont Center for Ecostudies, White River Junction, Vermont.

Hill, J.M., and J.D. Lloyd. 2017. A fine-scale U.S. population estimate of a montane spruce–fir bird species of conservation concern. Ecosphere 8:e01921. https://doi.org/10.1002/ecs2.1921

Hill, J.M., J.D. Lloyd, K.P. McFarland, and C.C. Rimmer. 2019. Apparent survival of a range-restricted montane forest bird species is influenced by weather throughout the annual cycle. Avian Conservation and Ecology 14:16. https://doi.org/10.5751/ACE-01462-140216

Hobson, K.A., K.P. McFarland, L.I. Wassenaar, C.C. Rimmer, and J.E. Goetz 2001. Linking breeding and wintering grounds of Bicknell's Thrushes using stable isotope analyses of feathers. Auk 118:16-23.

Holmes, R.T., and R.H. Sawyer. 1975. Oxygen consumption in relation to ambient temperature in five species of forest-dwelling thrushes (*Hylocichla* and *Catharus*). Comparative Biochemistry and Physiology 50A:527-531.

Hudson, M.-A.R., C.M. Francis, K.J. Campbell, C.M. Downes, A.C. Smith, and K.L. Pardieck. 2017. The role of the North American Breeding Bird Survey in conservation. Condor 119:526-545.

IBTCG. 2010. A conservation action plan for Bicknell's Thrush (*Catharus bicknelli*). J.A. Hart, C.C. Rimmer, R. Dettmers, R.M. Whittam, E.A. McKinnon, K.P. McFarland, (eds.) U.S. Fish and Wildlife Service, Hadley, Massachusetts, and Canadian Wildlife Service, Sackville, New Brunswick. 40 pp.

IUCN Standards and Petitions Committee. 2022. Guidelines for using the IUCN red list categories and criteria. Version 15. Prepared by the Standards and Petitions Committee. Website : https://www.iucnredlist.org/resources/redlistguidelines. [accessed 15 February 2022].

Iverson, L., A. Prasad, and S. Matthews. 2008. Modeling potential climate change impacts on trees of the northeastern United States. Mitigation and Adaptation Strategies for Global Change 13:487-516.

Jackson, A.K., D.C. Evers, M.A. Etterson, A.M. Condon, S.B. Folsom, J. Detweiler, J. Schmerfeld, and D.A. Christol. 2011. Mercury exposure affects the reproductive success of a free-living terrestrial songbird, the Carolina Wren (*Thryothorus ludovicianus*). Auk 128:759-769.

Jean-St-Laurent, É., pers. comm. 2021. *In email correspondence from I. Gauthier to R.D. Elliot.* September 2021. Direction de la conservation des habitats, des affaires législatives et des territoires fauniques, Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs, Quebec City, Quebec.

Julien, M.-F., G. Perreault, and M. Broeckaert. 2014. Identification des sites d'intervention prioritaires pour la Grive de Bicknell au Québec. Regroupement QuébecOiseaux, Montreal, Quebec. 23 pp.

Kouwenberg, A.-L. 2020. Mountain Birdwatch 2.0. 2019 report. Birds Canada – Atlantic Region. Sackville, New Brunswick.

Kouwenberg, A.-L., R. Torrenta, C. Ward, A.W. Diamond, and L. Tranquilla. 2020. Protection of Bicknell's Thrush Habitat in New Brunswick. Synthesis document. Birds Canada – Atlantic Region. Sackville, New Brunswick.

Lambert, J.D., K.P. McFarland, and C.C. Rimmer. 2017. Guidelines for managing Bicknell's Thrush habitat in the United States. High Branch Conservation Services, Hartland, Vermont.

Lambert, J.D., K.P. McFarland, C.C. Rimmer, S.D. Faccio, and J.L. Atwood. 2005. A practical model of Bicknell's Thrush distribution in the northeastern United States. Wilson Bulletin 117 :1-11.

Lauzon, E. 2010. Conservation de l'habitat de la Grive de Bicknell : guide d'aménagement forestier durable. Regroupement QuébecOiseaux, Montreal, Quebec.

Lawrence, G.B., P.W. Hazlett, I.J. Fernandez, R. Ouimet, S.W. Bailey, W.C. Shortle, K.T. Smith, and M.R. Antidormi. 2015. Declining acidic deposition begins reversal of forest-soil acidification in the northeastern U.S. and eastern Canada. Environmental Science and Technology 49:13103-13111.

Lemaître, J., pers. comm. 2021. *In email correspondence from I. Gauthier to R.D. Elliot.* September 2021. Biologist. Direction de l'expertise sur la faune terrestre, l'avifaune et l'herpétofaune, Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs , Quebec City, Quebec.

Lemaître, J., and V. Lamarre. 2020. Effects of wind energy production on a threatened species, the Bicknell's Thrush *Catharus bicknelli*, with and without mitigation. Bird Conservation International 30:194-209.

Lloyd, J.D., and K.P. McFarland (eds). 2017. A conservation action plan for Bicknell's Thrush (*Catharus bicknelli*). International Bicknell's Thrush Conservation Group. Website: http://bicknellsthrush.org/conservation-action-plan/conservation-action-plan-for-bicknells-thrush [accessed 5 February 2021].

Lutmerding, J.A., and A.S. Love. 2013. Longevity records of North American birds. Version 2013.3. Patuxent Wildlife Research Center. Bird Banding Laboratory. Laurel, Maryland.

Ma, Y., K.A. Hobson, K.J. Kardynal, C.G. Guglielmo, and B.A. Branfireun. 2021. Inferring spatial patterns of mercury exposure in migratory boreal songbirds: combining feather mercury and stable isotope (δ2H) measurements. Science of the Total Environment 762:143109. https://doi.org/10.1016/j.scitotenv.2020.143109

Martinsen, E.S., K.P. McFarland, and C.C. Rimmer. 2018. Documentation of a hybrid Bicknell's Thrush (*Catharus bicknelli*) x Veery (*Catharus fuscescens*) using vocalization and genetic data. Wilson Journal of Ornithology 130:70-80.

McDermott, J.P.B., D.M. Whitaker, and I.G. Warkentin. 2020. Constraints on range expansion of introduced red squirrels (*Tamiasciurus hudsonicus*) in an island ecosystem. Canadian Journal of Forest Research 50:1064-1073.

McFarland, K.P., J.D. Lloyd, S.J.K. Frey, P.L. Johnson, R.B. Chandler, and C.C. Rimmer. 2018. Modeling spatial variation in winter abundance to direct conservation actions for a vulnerable migratory songbird, the Bicknell's Thrush (*Catharus bicknelli*). Condor 120:517-529.

McFarland, K.P., C.C. Rimmer, J.E. Goetz, Y. Aubry, J.M. Wunderle Jr, A. Sutton, J. M. Townsend, A. L. Sosa, and A. Kirkconnell. 2013. A winter distribution model for Bicknell's Thrush (*Catharus bicknelli*), a conservation tool for a threatened migratory songbird. PLOS ONE 8(1):e53986. https://doi.org/10.1371/journal.pone.0053986

McFarland, K.P., and C.C. Rimmer. 2002. The relationship between cone mast, red squirrel populations and migratory songbird demographics in montane fir forests. 2001 Report to the Vermont Monitoring Cooperative. Vermont Institute of Natural Science, Woodstock, Vermont, USA. Website: https://www.uvm.edu/femc/attachments/project/999/reports/2001_Bird_Demographics_SquirrelCones_AnnualReport.pdf [accessed 5 February 2021].

McKinnon, E.A., H. Askanas, and A.W. Diamond. 2014. Nest-patch characteristics of Bicknell's Thrush in regenerating clear-cuts, and implications for precommercial thinning. Northeastern Naturalist 21:259-270.

MFFP. 2020. Aires infestées par la tordeuse des bourgeons de l'épinette au Québec en 2020. Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs, Gouvernement du Québec, Direction de la protection des forêts, Quebec City, Quebec. 31 p. Website: https://mffp.gouv.qc.ca/nos-publications/aires-infestees-tordeuse-bourgeons-epinette-2020/ [accessed 8 February 2021].

Morales, A., pers. comm. 2021. *Email correspondence with M.-A. Villard*. January 2021. Biologist. McGill Bird Observatory. Montreal, Quebec.

NatureServe. 2021. NatureServe Explorer: An online encyclopedia of life, Version 7.1. NatureServe, Arlington, Virginia. Website: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.106330/Catharus_bicknelli [accessed 5 February 2021].

Nixon, E.A., S.B. Holmes, and A.W. Diamond. 2001. Bicknell's Thrushes (*Catharus bicknelli*) in New Brunswick clear cuts: their habitat associations and co-occurrence with Swainson's Thrushes (*Catharus ustulatus*). Wilson Bulletin 113:33-40.

Ouellet, H. 1993. Bicknell's Thrush: taxonomic status and distribution. Wilson Bulletin 105:545-572.

Ouellet, H. 1995. Grive de Bicknell, *Catharus bicknelli*. Pp. 784-787 *in* J. Gauthier, and Y. Aubry (eds.). Les oiseaux du Québec : atlas des oiseaux nicheurs du Québec méridional. Canadian Wildlife Service, Environment Canada, Montreal, Quebec.

Partners in Flight. 2021. Species conservation profiles. Website: https://partnersinflight.org/species/bicknells-thrush/ [accessed 8 February 2021].

Plouffe Leboeuf, A., pers. Comm. 2022. *Email correspondence with M.-A. Villard*, January 2022. Ecologist, Parc national Forillon, Parks Canada Agency, Forillon, Quebec.

Poulin, J.-F., pers. comm. 2021. *Email correspondence with M.-A. Villard*. February 2021. Biologist and Team Leader/Environment, WSP, Baie-Comeau, Quebec.

Rimmer, C.C., pers. comm. 2021. *COSEWIC threat assessment call.* September 2021. Executive Director, Vermont Center for Ecostudies, White River Junction, Vermont.

Rimmer, C.C., J.D. Lloyd, K.P. McFarland, D.C. Evers, and O.P. Lane. 2019. Patterns of blood mercury variation in two long-distance migratory thrushes on Mount Mansfield, Vermont. Ecotoxicology 29:1174-1182.

Rimmer, C.C., K.P. McFarland, D.C. Evers, E.K. Miller, Y. Aubry, D. Busby, and R.J. Taylor. 2005. Mercury concentrations in Bicknell's Thrush and other insectivorous passerines in montane forests of northeastern North America. Ecotoxicology 14:223-240.

Robert, L.-E., B.R. Sturtevant, B.J. Cooke, P.M.A. James, M.-J. Fortin, P.A. Townsend, P.T. Wolter, and D. Kneeshaw. 2018. Landscape host abundance and configuration regulate periodic outbreak behavior in spruce budworm *Choristoneura fumiferana*. Ecography 41:1556-1571.

Robert, M., M.-H. Hachey, D. Lepage, and A.R. Couturier (eds). 2019. Deuxième atlas des oiseaux nicheurs du Québec méridional. Environment and Climate Change Canada, Regroupement QuébecOiseaux, and Bird Studies Canada. Montreal, Quebec. 694 pp.

Rodenhouse, N. L., S.N. Mathews, K.P. McFarland, J.D. Lambert, L.R. Iverson, A. Prassad, T.S. Sillett, and R.T. Holmes. 2008. Potential effects of climate change on birds of the Northeast. Mitigation and Adaptation Strategies for Global Change 13:517-540.

Rompré, G., V. Connolly, Y. Aubry, J.-P.L. Savard, and G. Seutin. 1999. Répartition, abondance et préférences écologiques de la Grive de Bicknell (*Catharus bicknelli*) au Québec. Technical Report. Canadian Wildlife Service. Quebec City, Quebec.

Salafsky, N., D. Salzer, A.J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S.H.M. Butchart, B. Collen, N. Cox, L.L. Master, S. O'Connor, and D. Wilkie. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology 22:897-911.

Sauer, A.K., C.T. Driscoll, D.C. Evers, E.M. Adams, and Y. Yang. 2020. Mercury exposure in songbird communities along an elevational gradient on Whiteface Mountain, Adirondack Park (New York, USA). Ecotoxicology 29:1830-1842.

Sauer, J R., D.K. Niven, J.E. Hines, D.J. Ziolkowski, Jr, K.L. Pardieck, J.E. Fallon, and W.A. Link. 2017. The North American Breeding Bird Survey, Results and Analysis 1966 – 2015. Version 2.07.2017 USGS Patuxent Wildlife Research Center, Laurel, Maryland. Website: https://www.pwrc.usgs.gov/bbs/ [accessed January 2021].

Savage, J., and M. Vellend. 2014. Elevational shifts, biotic homogenization and time lags in vegetation change during 40 years of climate warming. Ecography 38:546-555.

Smith, A., pers. comm. 2020. *Email correspondence with M.-A. Villard*. November 2020. Senior Statistician. Canadian Wildlife Service. Environment and Climate Change Canada, Ottawa, Ontario.

Smith, A., pers. comm. 2021. *Email correspondence with M.-A. Villard*. February 2021. Senior Statistician. Canadian Wildlife Service. Environment and Climate Change Canada, Ottawa, Ontario.

Smith, A., unpublished data 2021. Senior Statistician. Canadian Wildlife Service. Environment and Climate Change Canada, Ottawa, Ontario.

Smith, A.C., M.-A.R. Hudson, V.I. Aponte, and C.M. Francis, 2020. North American Breeding Bird Survey – Canadian Trends Website, Data-version 2019. Environment and Climate Change Canada, Gatineau, Quebec. Website: https://wildlife-species.canada.ca/breeding-bird-survey-results. [accessed August 2021].

Smith, C., K.F. Beazley, P. Duinker, and K.A. Harper. 2010. The impact of moose (*Alces alces andersoni*) on forest regeneration following a severe spruce budworm outbreak in the Cape Breton Highlands, Nova Scotia, Canada. Alces 46:135-150.

Sopuck, L., K. Ovaska, and B. Whittington. 2002. Responses of songbirds to aerial spraying of the microbial insecticide *Bacillus thuringiensis* var. Kurstaki (Foray 48B) on Vancouver Island, British Columbia, Canada. Environmental Toxicology and Chemistry 21:1664-1672.

Stewart, R.L.M., K.A. Bredin, A.R. Couturier, A.G. Horn, D. Lepage, S, Makepeace, P.D. Taylor, M.-A. Villard, and R.M. Whittam (eds). 2015. Second Atlas of the Breeding Birds of the Maritime Provinces. Environment Canada, Bird Studies Canada, Natural History Society of Prince Edward Island, Nature New Brunswick, Nova Scotia Bird Society, Nova Scotia Department of Natural Resources, New Brunswick Department of Natural Resources, Prince Edward Island Department of Agriculture and Forestry. Sackville, New Brunswick. 528 + 28 pp.

Stralberg, D., D. Berteaux, C.R. Drever, M. Drever, I. Naujokaitis-Lewis, F.K.A. Schmiegelow, and J.A. Tremblay. 2019. Conservation planning for boreal birds in a changing climate: a framework for action. Avian Conservation and Ecology 14:13. https://doi.org/10.5751/ACE-01363-140113

Strong, A.M., C.C. Rimmer, and K.P. McFarland. 2004. Effect of prey biomass on reproductive success and mating strategy of Bicknell's Thrush (*Catharus bicknelli*), a polygynandrous songbird. Auk 121:446-451.

Studds, C.E., K.P. McFarland, Y. Aubry, C.C. Rimmer, K.A. Hobson, P.P. Marra, and L.I. Wassenaar. 2012. Stable-hydrogen isotope measures of natal dispersal reflect observed population declines in a threatened migratory songbird. Diversity and Distributions 18:919-930.

Studds, C.E., and P.P. Marra. 2005. Nonbreeding habitat occupancy and population processes: an upgrade experiment with a migratory bird. Ecology 86:2380-2385.

Taylor, P.D., T.L. Crewe, S.A. MacKenzie, D. Lepage, Y. Aubry, Z. Crysler. G. Finney, C.M. Francis, C.G. Guglielmo, D.J. Hamilton, R.L. Holberton, P.H. Loring, G.W. Mitchell, D.R. Norris, J. Paquet, R.A. Ronconi, J.R. Smetzer, P.A. Smith, L.J. Welch, and B.K. Woodworth. 2017. The Motus wildlife tracking system: a collaborative research network to enhance the understanding of wildlife movement. Avian Conservation and Ecology 12(1):8. https://doi.org/10.5751/ACE-00953-120108

Todd, W.E.C. 1963. Birds of the Labrador Peninsula and Adjacent Areas. University of Toronto Press, Toronto, Ontario.

Torrenta, R. 2021a. ARU projects in New Brunswick: summary report. Birds Canada – Atlantic Region. Sackville, New Brunswick.

Torrenta, R. 2021b. High Elevation Landbird Program Mountain Birdwatch 2.0. 2020 report. Birds Canada – Atlantic Region. Sackville, New Brunswick. 16 pp.

Torrenta, R., pers. comm. 2021. *Email correspondence with M.-A. Villard*. September 2021. Biologist, Birds Canada, Sackville, New Brunswick.

Townsend, J.M., K.P. McFarland, C.C. Rimmer, W.G. Ellison, and J.E. Goetz. 2020. Bicknell's Thrush (*Catharus bicknelli*). Version 1.0. Text last updated August 13, 2015, *in* P.G. Rodewald (ed.). Birds of the World. Cornell Laboratory of Ornithology, Ithaca, New York. Website: https://doi.org/10.2173/bow.bicthr.01

Townsend, J.M., C.C. Rimmer, J. Brocca, K.P. McFarland, and A.K. Townsend. 2009. Predation of a wintering migratory songbird by introduced rats: can nocturnal roosting behavior serve as predator avoidance? Condor 111:565-569.

Townsend, J.M., C.C. Rimmer, C.T. Driscoll, K.P. McFarland, and E. Iñigo-Elias. 2013. Mercury concentrations in tropical resident and migrant songbirds on Hispaniola. Ecotoxicology 22:86-93.

Townsend, J.M., C.C. Rimmer, and K.P. McFarland. 2010. Winter territoriality and spatial behavior of Bicknell's Thrush (*Catharus bicknelli*) at two ecologically distinct sites in the Dominican Republic. Auk 127:514-522.

Townsend, J.M., C.C. Rimmer, and K.P. McFarland. 2012. Radio-transmitters do not affect seasonal mass change or annual survival of wintering Bicknell's Thrushes. Journal of Field Ornithology 83:295-301.

Townsend, J.M., C.C. Rimmer, A.K. Townsend, and K.P. McFarland. 2011. Sex and age ratios of Bicknell's Thrush wintering in Hispaniola. Wilson Journal of Ornithology 123:367-372.

US EPA. 2014. 2014 program progress – Clean Air Interstate Rule, Acid Rain Program, and former Nox Budget Trading Program. Website: https://www.epa.gov/sites/default/files/2017-09/documents/2014_full_report.pdf [accessed 4 January 2021].

US FWS. 2017. Service finds migratory songbird does not warrant Endangered Species Act protection. Website: https://ecos.fws.gov/ecp/species/606 [accessed January 2021].

Wallace, G.J. 1939. Bicknell's Thrush, its taxonomy, distribution, and life history. Proceedings of the Boston Society of Natural History 41:211-402.

Ward, C. 2020. Breeding home range and habitat use of a rare high-elevation songbird in industrial forests of New Brunswick. Ph.D. thesis, University of New Brunswick, Fredericton, New Brunswick.

Whitney, M.C., and D.A. Cristol. 2017. Impacts of sublethal mercury exposure on birds: a detailed review. Reviews of Environmental Contamination and Toxicology 244:113-163.

Whittam, B. 2015. Bicknell's Thrush, *Catharus bicknelli*. Pp. 390-391 *in* R.L.M. Stewart, K.A. Bredin, A.R. Couturier, A.G. Horn, D. Lepage, S. Makepeace, P.D. Taylor, M.-A. Villard, and R.M. Whittam (eds.). Second atlas of the breeding birds of the Maritime Provinces. Environment Canada, Bird Studies Canada, Natural History Society of Prince Edward Island, Nature New Brunswick, Nova Scotia Bird Society, Nova Scotia Department of Natural Resources, New Brunswick Department of Natural Resources, Prince Edward Island Department of Agriculture and Forestry. Sackville, New Brunswick. 528 + 28 pp.

Wild Species. 2015. The general status of species in Canada. Website: http://wildspecies.ca [accessed 4 January 2021].

Wilson, J., pers. comm. 2021. *Email correspondence with M.-A. Villard*. February 2021. Amateur ornithologist. Quispamsis, New Brunswick.

Wilson, M.D., and B.D. Watts. 1997. Autumn migration of Gray-cheeked and Bicknell's Thrushes at Kiptopeke, Virginia. Journal of Field Ornithology 68:519-525.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

Marc-André Villard is an avian ecologist focusing on population response to forest management and landscape-level processes. His PhD research investigated the effects of habitat fragmentation on the distribution and pairing success of focal passerine species including Wood Thrush (*Hylocichla mustelina*) and Ovenbird (*Seiurus aurocapilla*). More recently, he examined the effects of intensive forest management on demographic parameters of focal species, including Swainson's Thrush, through large-scale field experiments, as well as trophic relationships linking mast-seeding trees, rodents, and songbird reproduction. His field research has mainly been conducted in temperate and boreal forests of Quebec, New Brunswick, and Alberta. Dr. Villard was a founding co-editor of Avian Conservation and Ecology. He works in Quebec as a Conservation Biologist with Sépaq on projects addressing species at risk, invasive species, and the effects of outdoor recreation on biodiversity.

COLLECTIONS EXAMINED

No collections were examined in the preparation of this report.

Appendix 1. Threats Calculator results for Bicknell's Thrush

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	Bicknell's Thrush *Catharus bicknelli*			
Element ID		**Elcode**		
Date (Ctrl + ";" for today's date):	2021-09-07			
Assessor(s):	David Fraser (facilitator), Marc-André Villard (writer), Richard Elliot (Birds SSC co-chair), Sydney Allen (COSEWIC Secretariat), Christian Artuso, Yves Aubry, Louise Blight, Greg Campbell, Pete Davidson, Tony Diamond, Marcel Gahbauer, Adam Hadley, Andrew Horn, Tara Imlay, Mary Sabine, Jean-Pierre Savard, Peter Thomas, Junior Tremblay, Rémi Torrenta, Chris Rimmer, Liana Zanette, Erin Whidden, Chris Ward			
References:	Draft threats calculator, draft Bicknell's Thrush status report, threats spreadsheet from the Bicknell's Thrush Recovery Strategy (ECCC 2020).			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	2	0
	D	Low	3	5
Calculated Overall Threat Impact:			High	Medium
Assigned Overall Threat Impact:			**High-Medium**	
Impact Adjustment Reasons:				
Overall Threat Comments			Generation time for Bicknell's Thrush is approximately 2.3 years (Bird *et al.* 2020), so the time frame for considering severity and timing is 10 years. Threats are considered on breeding grounds in QC, NB, and NS, on migration through the eastern United States, and on wintering grounds in the Greater Antilles islands in the Caribbean Sea, where impacts of many threats may be highest.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1–10%)	Slight (1–10%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1–10%)	Slight (1–10%)	High (Continuing)	No housing or urban development is expected on the breeding or wintering grounds, although some migratory stopover sites may be affected through loss of habitat and direct building strikes from urban development.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.2	Commercial & industrial areas	D	Low	Small (1–10%)	Slight (1–10%)	High (Continuing)	Little commercial or industrial development is expected on the breeding or wintering grounds, although some migratory stopover sites may be affected. Construction of telecommunication towers in breeding areas at high elevations may be a local threat through loss of nesting habitat.
1.3	Tourism & recreation areas	D	Low	Small (1–10%)	Slight (1–10%)	High (Continuing)	The development of skiing resorts, ski slopes, and backcountry trails causes direct habitat loss due to forest clearing, although Bicknell's Thrush has been shown to nest successfully at trail edges.
2	Agriculture & aquaculture	D	Low	Restricted (11–30%)	Moderate (11–30%)	High (Continuing)	
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11–30%)	Moderate (11–30%)	High (Continuing)	Shifting and industrial agriculture continue to cause deforestation and habitat degradation on the wintering grounds, although areas used for shifting agriculture eventually regenerate to usable forest habitat.
2.2	Wood & pulp plantations						Not an issue on the breeding or wintering grounds.
2.3	Livestock farming & ranching	D	Low	Small (1–10%)	Slight (1–10%)	High (Continuing)	Expansion of small-scale cattle ranching and clearing may cause some loss of forested habitat on wintering grounds.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining	D	Low	Restricted – Small (1–30%)	Slight (1–10%)	High (Continuing)	
3.1	Oil & gas drilling		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, <10 yrs/3 gen)	No interaction documented between Bicknell's Thrush and oil and gas drilling but may occur occasionally on migration.
3.2	Mining & quarrying						No significant interaction expected between Bicknell's Thrush and quarry or mining activity, at any time of year.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
3.3	Renewable energy	D	Low	Restricted – Small (1–30%)	Slight (1–10%)	High (Continuing)	Wind energy developments in remote mountain-top breeding habitat of Quebec and New Brunswick may cause disturbance and habitat loss through construction and use of access roads and clearing of turbine pads at wind farms, with potential for occasional direct strike mortality.
4	Transportation & service corridors		Negligible	Restricted – Small (1–30%)	Negligible (<1%)	High (Continuing)	
4.1	Roads & railroads		Negligible	Restricted – Small (1–30%)	Negligible (<1%)	High (Continuing)	Most areas used for breeding and in winter are remote and isolated from road and railway corridors, except for infrequently used access roads to wind farms, communication towers, forestry areas, or agricultural fields.
4.2	Utility & service lines		Negligible	Negligible (<1%)	Slight (1–10%)	High (Continuing)	Clearing, construction, and maintenance of high voltage power lines and corridors may cause limited disturbance and habitat loss in breeding areas. Telecommunication towers in breeding areas may be a local threat due to possible direct strike mortality.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	CD	Medium – Low	Large – Restricted (11–70%)	Moderate (11–30%)	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	CD	Medium – Low	Large – Restricted (11–70%)	Moderate (11–30%)	High (Continuing)	Approximately 90% of breeding habitat occurs within managed forest lands. Broad-scale precommercial thinning in dense regenerating spruce-fir forests results in recently thinned stands, which are avoided by breeding Bicknell's Thrush for several years. Recent research in New Brunswick suggests that Bicknell's Thrush may prefer older conifer stands, adding to its vulnerability to intensive forest management. Wide-spread replanting of harvested Balsam Fir with spruce in Quebec and the Maritimes results in conversion of forest type and loss of primary fir breeding habitat. Resulting extensive spruce plantations likely support much higher densities of cone-hoarding Red Squirrel, with consequent increases in nest predation pressure (**see 8.2 Problematic Native Species/Diseases**). On the wintering grounds, timber harvesting for charcoal production may cause habitat loss on a local scale.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Small (1–10%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Small (1–10%)	Negligible (<1%)	High (Continuing)	Most nest sites and wintering areas are in dense woodlands far from trails and human access routes. Increasing outdoor recreation (e.g., hiking, mountain biking, downhill and cross-country ski trails) may impose some pressure on breeding habitat and may occasionally be heavy along trails in some protected areas, although a study on the effects of hiking trail use in the White Mountains of New Hampshire (DeLuca and King 2014) suggests that impacts on occurrence and abundance are minimal.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Research on Bicknell's Thrush may have limited effects on abundance on a local scale. However, the absence of effects of radio-transmitters on apparent survival reported by Townsend *et al.* (2012) suggests that the species is fairly robust to such disturbance.
7	Natural system modifications		Unknown	Unknown	Moderate – Slight (1–30%)	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Unknown	Moderate – Slight (1–30%)	High (Continuing)	Climate change models (Cadieux *et al.* 2019) predict increased frequency of wildfires within the boreal forest. Scope is unknown as additional impact of such wildfires compared to other factors has not been estimated and as fire can have positive effects by stimulating natural succession. Fire suppression is unlikely to have a significant effect in the remote areas occupied by this species.
7.2	Dams & water management/use						No large-scale water management projects are expected within the boreal breeding range over the next decade, and most projects have little direct effect on Bicknell's Thrush, which breeds at relatively high elevations.
7.3	Other ecosystem modifications						Other human activities that modify habitats in the breeding or wintering areas, other than those related to changing climates considered in section **11.1 (Habitat shifting & alteration)**, are unlikely to affect Bicknell's Thrush or its food resources.
8	Invasive & other problematic species & genes	CD	Medium – Low	Pervasive (71–100%)	Moderate – Slight (1–30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species/diseases	D	Low	Pervasive (71–100%)	Slight (1–10%)	High (Continuing)	Introduced predators (e.g. Black and Norway Rat, domestic cat, mongoose) have been shown to kill Bicknell's Thrush roosting in trees at night on the wintering grounds. Rats occur in all wintering areas studied on Hispaniola, including forests where females overwinter, and may cause Bicknell's Thrush to move from preferred habitat to adjacent pine forests. Feral pigs may cause limited habitat degradation in wintering areas.
8.2	Problematic native species/diseases	CD	Medium – Low	Pervasive (71–100%)	Moderate – Slight (1–30%)	High (Continuing)	As Red Squirrel numbers are subsidized in part by the conversion of Balsam Fir-dominated forests to spruce plantations through forest management activities, their impacts are considered to exceed natural levels, likely increasing levels of nest predation, especially in years of spruce cone crop failure. Ongoing Spruce Budworm outbreaks, whose intensity is likely increased above natural levels by forest management techniques that create even-aged stands, may degrade breeding habitat in Quebec and the Maritime provinces within the next 10 years. Longer-term effects of budworm causing forest succession may be more positive. Overabundant Moose in Cape Breton has also degraded breeding habitat, and some impacts may be expected in limited parts of the range.
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		Unknown	Pervasive (71–100%)	Unknown	High (Continuing)	
9.1	Domestic & urban waste water						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Restricted – Small (1–30%)	Unknown	High (Continuing)	Spraying forests with Btk to control Spruce Budworm and Hemlock Looper numbers may reduce food abundance by killing Lepidopteran larvae, including Spruce Budworm, which are eaten by Bicknell's Thrush.
9.4	Garbage & solid waste						
9.5	Airborne pollutants		Unknown	Pervasive (71–100%)	Unknown	High (Continuing)	Atmospheric deposition of mercury and other pollutants, such as lead, nitrogen, and sulphur dioxides, may have direct effects on health of Bicknell's Thrush, although impacts have not been documented and recorded contaminant levels are relatively low. Acid precipitation may have negative effects, especially at high elevations, through calcium depletion and increased uptake of aluminum, lead, and other heavy metals in invertebrate food.
9.6	Excess energy						
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		Negligible	Pervasive (71–100%)	Negligible (<1%)	High (Continuing)	Reductions in the extent and quality of breeding habitat are predicted by climate change modelling, especially through reductions in the extent of Balsam Fir stands at high elevations or on plateaus as temperatures rise, resulting in suitable habitat moving upslope and northwards, and decreasing in overall extent. Many effects may take place beyond 10 years, especially in higher habitats.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts		Unknown	Pervasive (71–100%)	Unknown	High (Continuing)	Projecting drying trend has already begun in moist forests used on wintering grounds, with uncertain but presumed negative effects on Bicknell's Thrush.
11.3	Temperature extremes						No evidence of impacts of increasing temperatures on breeding or wintering grounds.
11.3	Storms & flooding		Unknown	Pervasive (71–100%)	Unknown	High (Continuing)	Increased frequency and intensity of storms throughout the year, and hurricanes during fall migration, may increase mortality. More severe and frequent hurricanes are already significantly modifying lower and higher elevation wintering habitats in the Dominican Republic.
12	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							