COSEWIC
Assessment and Status Report

on the

Rusty-patched Bumble Bee
Bombus affinis

in Canada

ENDANGERED
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:

COSEWIC. 2022. COSEWIC assessment and status report on the Rusty-patched Bumble Bee *Bombus affinis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 56 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Previous report(s):

COSEWIC. 2010. COSEWIC assessment and status report on the Rusty-patched Bumble Bee *Bombus affinis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 34 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Production note:
Production note: COSEWIC would like to acknowledge Dr. Sheila Colla, Dr. Amanda Liczner, and Dr. Victoria MacPhail for writing the status report on Rusty-patched Bumble Bee, *Bombus affinis*, in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by David McCorquodale, Co-chair of the COSEWIC Arthropods Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
www.cosewic.ca

Également disponible en français sous le titre « Évaluation et Rapport de situation du COSEPAC sur le Bourdon à tache rousse (*Bombus affinis*) au Canada. »

Cover illustration/photo:
Rusty-patched Bumble Bee — Photograph by Zach Portman.

Catalogue No. CW69-14/598-2023E-PDF
ISBN 978-0-660-48473-0

COSEWIC
Assessment Summary

Assessment Summary – December 2022

Common name
Rusty-patched Bumble Bee

Scientific name
Bombus affinis

Status
Endangered

Reason for designation
This bee was once found throughout southern Ontario, Quebec, and east into western New Brunswick. Focused, intensive searches throughout the Canadian range have not detected this bumble bee since 2009. Pathogens from, and competition with, non-native and managed bees are believed to be the primary causes of the initial decline and remain serious threats. Additionally, habitat quality continues to decline as a result of changes in agricultural practices and increasing development. Climate change is an additional ongoing threat. These threats could lead to extirpation of the species in Canada within the next 10 years.

Occurrence
Ontario, Québec, New Brunswick

Status history
Designated Endangered in April 2010. Status re-examined and confirmed in December 2022.

COSEWIC
Executive Summary

Rusty-patched Bumble Bee
Bombus affinis

Wildlife Species Description and Significance

The Rusty-patched Bumble Bee is a large bumble bee which forages from April through October, a long active season for bumble bees. Workers and males have a distinct rusty brown patch on their abdomens. Queens are large and can be difficult to distinguish from other species using colour pattern alone. The long flight season and generalist nature of this species make it an important pollinator for many native flowering plants as well as agricultural crops. It has special significance as one of the first native bee species documented to have declined significantly throughout its extensive range and the first bee to be federally listed in both Canada and the United States (USA).

Distribution

In Canada, the Rusty-patched Bumble Bee historically occurred in southern Ontario, southern Quebec, and western New Brunswick. In the USA, the range extends from Minnesota east to Maine, and south to northern Georgia. There have been no records of the species in Canada since 2009 (Pinery Provincial Park, ON), despite significant search effort since 2010. While the species has also declined in the United States, it can still be found in some regions, particularly the Midwest.

Habitat

The Rusty-patched Bumble Bee uses wooded areas, upland forests, oak savannah, tallgrass prairie, open prairie, wetlands, meadows, urban areas, and agricultural areas. In Canada, it has been found in the Great Lakes Plains and Atlantic Maritime Ecozones. Like all bumble bees, the Rusty-patched Bumble Bee has distinct requirements for nesting, foraging, and overwintering. Because of the long colony cycle, nectar and pollen from flowers must be available from early spring to fall. These bees most often nest and overwinter underground, likely in wooded areas with well-drained soil.

Biology

Rusty-patched Bumble Bees are eusocial and have a foundress queen. Individuals have multiple forms over their lifetime (i.e., larva, pupa, adult). The nest grows after initiation by the solitary queen, with workers taking over the foraging and nest care duties through the summer. The colony cycle ends in late summer or early fall, when gynes (large females capable of becoming queens) and males are produced. Gynes and males mate in late summer or early autumn. Only mated females overwinter. Dispersal distances for Rusty-patched Bumble Bee are unknown, but extrapolating from bumble bees in the same subgenus, maximum dispersal rates are about 10 km/year. The Rusty-patched Bumble Bee visits many flowering plant species to collect nectar and/or pollen, often pollinating the plants visited. The Gypsy Cuckoo Bumble Bee (Endangered) is a social parasite which uses the Rusty-patched Bumble Bee, along with other species in the same subgenus, as a host. Small mammals that create burrows may play an important role in creating nest sites for the Rusty-patched Bumble bee, but this needs further investigation. Many animals feed on adult bumble bees and larvae in nests.

Population Sizes and Trends

Rusty-patched Bumble Bee numbers have been in decline for the last few decades, and the species has not been seen in Canada since 2009. Studies show consistent declines on the basis of both relative abundance and range occupancy metrics. Because the Rusty-patched Bumble Bee has not been detected in Canada in the past decade (2010–2020), and given that there has been an increase in search effort, it can be assumed that the population is likely smaller than in the previous decade (2000–2010), when only one individual was seen in the St. Williams Conservation Reserve (Manester Tract), Ontario and three individuals at Pinery Provincial Park in Ontario.

Threats and Limiting Factors

Current threats to remnant subpopulations include pathogen spillover, habitat loss through agricultural intensification, resource extraction, urbanization and other types of land development, competition from introduced bees, pesticides, and climate change (including extreme weather events). All threats within its historical range are current and ongoing, with climate change likely to become more important. Given the speed and extent of decline and evidence from studies of closely related species, pathogen spillover is considered the most likely explanation for the previous decline. Small subpopulation sizes likely now exacerbate these threats due to lack of genetic diversity and limited gene flow.

Protection, Status and Ranks

In Canada, the Rusty-patched Bumble Bee is listed as Endangered under both the federal *Species at Risk Act* and the Ontario *Endangered Species Act*. In Quebec it is included on the *Liste des espèces susceptibles d'être désignées menacées ou vulnérables* (List of wildlife species likely to be designated threatened or vulnerable), which is produced pursuant to the *Loi sur les espèces menacées ou vulnérables* (RLRQ, c E-12.01) (LEMV) (Act respecting threatened or vulnerable species) (CQLR, c E-12.01). It is also federally listed as Endangered in the USA under the *Endangered Species Act*.

It is globally ranked as Imperilled (G2), and in Canada nationally ranked as Critically Endangered (N1), and provincially ranked as Critically Endangered (S1) in Ontario and Quebec and as Possibly Extirpated (SH) in New Brunswick. The species is listed as Critically Endangered (CR) on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species.

TECHNICAL SUMMARY

Bombus affinis

Rusty-patched Bumble Bee

Bourdon à tache rousse

Range of occurrence in Canada: Ontario, Quebec, New Brunswick

Demographic Information

Generation time	1 yr.
Is there an observed continuing decline in number of mature individuals?	No, but none observed since 2009, so decline assumed
Estimated percent of continuing decline in total number of mature individuals within 5 years.	Unknown, but decline assumed since none observed since 2009
[Observed, estimated, inferred, or suspected] percent reduction in total number of mature individuals over the last 10 years.	Unknown but decline assumed since none observed since 2009
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 10 years.	Unknown but decline assumed to continue
[Observed, estimated, inferred, or suspected] percent reduction in total number of mature individuals over any period 10 years, including both the past and the future.	Unknown, could be as high as 100%
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a) No b) Partially c) No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	203 km^2 for 2000–2010; 0–203 km^2 for 2011–2021
Index of area of occupancy (IAO) (Always report 2x2 grid value).	16 km^2 for 2000–2010; 0–16 km^2 for 2011–2021
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?	Unknown

Number of “locations”*	0–3, recognizing potential that it persists
Is there an observed decline in extent of occurrence?	Assumed decline, not detected since 2009
Is there an observed decline in index of area of occupancy?	Assumed decline, not detected since 2009.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes inferred, not detected since 2009
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Yes inferred, not detected since 2009
Is there an inferred decline in quality of habitat?	Yes, land cover changes including intensifying agriculture and urbanization have resulted in habitat degradation.
Are there extreme fluctuations in number of subpopulations?	No
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

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**No Mature Individuals**
	Unknown, but reasonably <250 (possibly extirpated given no observations since 2009)
Total	

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]?	n/a

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

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

Was a threats calculator completed for this species? A recent threats assessment for the federal recovery strategy is available and is reproduced here. The IUCN threats that impact the Rusty-patched Bumble Bee are listed below, ranked according to impact based on the 2020 Recovery Strategy, with two threats added. 8.1 Invasive non-native/alien species 9.3 Agricultural and forestry effluents 11 Climate change and severe weather 2.1 Annual and perennial non-timber crops 1.1 Housing and urban areas 1.2 Commercial and industrial areas 4.1 Roads and railroads 8.2 Invasive non-native/alien species and problematic native species 2.3 Livestock farming and ranching 7.1 Fire and fire suppression 5.3: Logging and wood harvesting

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Michigan, Ohio, Pennsylvania, New York, Maine (SH); Wisconsin, Indiana, Vermont (S1)
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes, but declining due to land cover changes from urbanization and agricultural intensification as well as risk of pathogen spillover from managed bees used in agriculture.
Are conditions deteriorating in Canada?+	Yes, increased use of managed bees, climate change, land use changes.
Are conditions for the source (i.e., outside) population deteriorating?+	Yes
Is the Canadian population considered to be a sink?+	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

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

Status History

COSEWIC Status History: Designated Endangered in April 2010. Status re-examined and confirmed in December 2022.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** B2ab(iii); C2a(i); D1
Reasons for designation: This bee was once found throughout southern Ontario, Quebec, and east into western New Brunswick. Focused, intensive searches throughout the Canadian range have not detected this bumble bee since 2009. Pathogens from, and competition with, non-native and managed bees are believed to be the primary causes of the initial decline and remain serious threats. Additionally, habitat quality continues to decline as a result of changes in agricultural practices and increasing development. Climate change is an additional ongoing threat. These threats could lead to extirpation of the species in Canada within the next 10 years.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable, no observations in the past 10 years.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B2ab(iii). IAO (0–16 km²) is below threshold for Endangered and the population exists in <5 locations. Since no observations since 2009, there is an inferred ongoing decline in habitat quality based on ongoing threats, pathogens and competition with non-native and managed bees. May meet B1, small EOO, but, difficult to demonstrate because if a few subpopulations remain, they may be widely separated.
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered, C2a(i). Population inferred to be much fewer than 2,500 and no subpopulation with more than 250 individuals, based on no observations since 2009.
Criterion D (Very Small or Restricted Population): Meets Endangered, D1. Population inferred to be <250 based on no observations since 2009.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

PREFACE

The Rusty-patched Bumble Bee was previously a common species in its historical Canadian range in southern Ontario and Quebec, and less common in western New Brunswick. It experienced rapid declines in the 1980s and 1990s and, as a result, was listed as Endangered in Canada. The species remains rare, or possibly extirpated, in Canada as no individuals have been found since 2009 despite extensive search effort and public interest. It is still found in parts of its range, primarily Minnesota, Iowa, Wisconsin, and Illinois.

Multiple lines of evidence, including the speed and extent of decline and studies of closely related species, suggest pathogen spillover from managed bees is a major cause of the decline. Threats to remnant subpopulations include pathogen spillover (*Crithidia bombi, Vairimorpha bombi* [formerly *Nosema bombi*]*, Apicystis bombi, Sphaerularia bombi*), tracheal mites, and viruses. In Canada, pathogen screening did not occur while the Rusty-patched Bumble Bee was widespread but only after it had declined. It is unclear which pathogen(s) from managed bees (e.g., the introduced Western Honey Bee, *Apis mellifera*, and managed bumble bees, such as the Common Eastern Bumble Bee, *Bombus impatiens*) were involved. Other factors likely include habitat loss through agricultural intensification, resource extraction and development, competition from managed bees, pesticides, and climate change. All of these contribute to a lack of the floral resources needed to support colony development. Small subpopulation size likely exacerbates these factors due to lack of genetic diversity and limited movement and gene flow. Little is known about the cumulative impacts of these threats.

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.

COSEWIC Status Report

on the

Rusty-patched Bumble Bee
Bombus affinis

in Canada

2022

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Phylum Arthropoda – Arthropods
Class Insecta – Insects
Order Hymenoptera – Bees, Ants and Wasps
Family Apidae
Genus *Bombus* – Bumble Bees
Subgenus *Bombus sensu stricto*
Species *B. affinis* Cresson, 1863 Rusty-patched Bumble Bee

French common name: Bourdon à tache rousse

English common name: Rusty-patched Bumble Bee

Bumble bees are a genus (*Bombus* Latreille 1802) in the family Apidae (Williams *et al*. 2014). The Rusty-patched Bumble Bee was described by Cresson in 1863 and taxonomy has been stable since then (Cameron *et al*. 2007; Williams *et al*. 2014).

Morphological Description

Rusty-patched Bumble Bee is a large bee (Williams *et al*. 2014) with dense, even hairs. The eggs, larvae, and pupae are not described. Adult body sizes are 19–23 mm for queens, 9–16 mm for workers, and 14–17 mm for males (Williams *et al*. 2014). The cheek (ocular-malar area) is shorter than broad (Williams *et al*. 2014). Workers and males have a characteristic rusty brown patch on the second tergite (T2) or abdominal stripe (Figures 1, 2). Unmated gynes and queens have primarily yellowish hairs on their entire T2 segment (Figure 3). Hairs on the face and head are primarily black in all castes (queen, worker, and male).

Similar co-occurring species include the Tri-coloured Bumble Bee (*B. ternarius*), Brown-belted Bumble Bee (*B. griseocollis*), and Red-belted Bumble Bee (*B. rufocinctus*). Queens/unmated gynes may be confused with Half-black Bumble Bee (*B. vagans*) and Sanderson's Bumble Bee (*B. sandersoni*). Males may be confused with Lemon Cuckoo Bumble Bee (*B. citrinus*). For more details on identification in the field or with a microscope and a dichotomous key, see Williams *et al*. (2014).

Figure 1. Rusty-patched Bumble Bee worker collected at Pinery Provincial Park, Ontario, 2009 (Photo by S. Colla, specimen at York University).

Figure 2. Male Rusty-patched Bumble Bee collected at Pinery Provincial Park, Ontario, 2005 (Photo by C. Ratti, specimen at York University).

Figure 3. Rusty-patched Bumble Bee queen collected in 1971 at the Thousand Islands, Ontario (Photo by S. Colla, specimen at York University).

Population Spatial Structure and Variability

In Canada, the spatial structure and genetic variability of the Rusty-patched Bumble Bee have not been studied, largely due to its rarity. Similarly, no genetic studies have been done in Canada or elsewhere. DNA barcodes of CO1 for three specimens, including two from Canada (one from Pinery Provincial Park 2009 and one from 'Ontario') are available through BOLD (2022).

Designatable Units

The Rusty-patched Bumble Bee has no recognized subspecies. It is considered to be one designatable unit within Canada. The species has been found in the Great Lakes Plains and Atlantic Maritime Ecozones of Canada (COSEWIC 2018).

Special Significance

The family Apidae includes many species such as the economically important bumble bees and honey bees. As the first bee species to be listed as Endangered in both the USA and Canada, the Rusty-patched Bumble Bee has sociocultural significance which has sparked "save the bee" movements in North America (note that many of these movements now target bees in general, not just this single species). Pollinator conservation has become a top environmental issue among Canadians over the past decade (2010–2020) (van Vierssen Trip *et al.* 2020) and this is in part due to the rapid decline of this distinctive and charismatic bee. Community science programs and pollinator gardens have resulted from this sustained public interest.

The Rusty-patched Bumble Bee is a generalist native pollinator with a long flight period (April through October), meaning that it visits and can pollinate a large variety of native plants and agricultural crops. Generalist bumble bees, including the Rusty-patched Bumble Bee, are important ecosystem service providers that help ensure the sustainability of intact ecosystems and help pollinate human food plants in agricultural and urban lands. As noted in the previous COSEWIC status report (2010), bumble bees are of special significance to Indigenous peoples. They are depicted in totems, artwork, ceremonial masks, and stories. Many culturally important medicinal and food plants have co-evolved with native pollinators, and culturally important animals subsist on pollinated food (e.g., Black Bears [*Ursus americanus*] and wild blueberries [*Vaccinium* spp.]).

The Rusty-patched Bumble Bee is not the only at-risk species in its subgenus. In North America, of the five species in the subgenus *Bombus sensu stricto* Latreille, four are experiencing declines according to COSEWIC and IUCN assessments: Western Bumble Bee (*Bombus occidentalis* (Vulnerable, IUCN; ssp. *occidentalis*, Threatened, COSEWIC; ssp. *mckayi*, Special Concern, COSEWIC), Franklin's Bumble Bee, *B. franklini* (Critically Endangered, IUCN), Yellow-banded Bumble Bee, *B. terricola* (Vulnerable, IUCN; Special Concern, COSEWIC), Rusty-patched Bumble Bee (Critically Endangered, IUCN, Endangered COSEWIC), and Cryptic Bumble Bee, *B. cryptarum* (Data Deficient, IUCN)). Note that Williams (2021) elevated *Bombus occidentalis* ssp. *mckayi* to full species further to these assessments.

DISTRIBUTION

Global Range

The Rusty-patched Bumble Bee historically occurred in southern Ontario, southern Quebec, and western New Brunswick and throughout the northeastern United States. The current range is much smaller in both countries (Jepsen *et al.* 2013; Williams *et al*. 2014; USFWS 2019; ECCC 2020) (Figure 4).

The historical global range (EOO) (Extent of Occurrence) is 2,621,644 km^2. The Canadian range is 7.76% of the global range (see EOO for Canadian range below). These values were calculated using the data sources in Figure 4 and include the area of major water bodies (e.g., the Great Lakes).

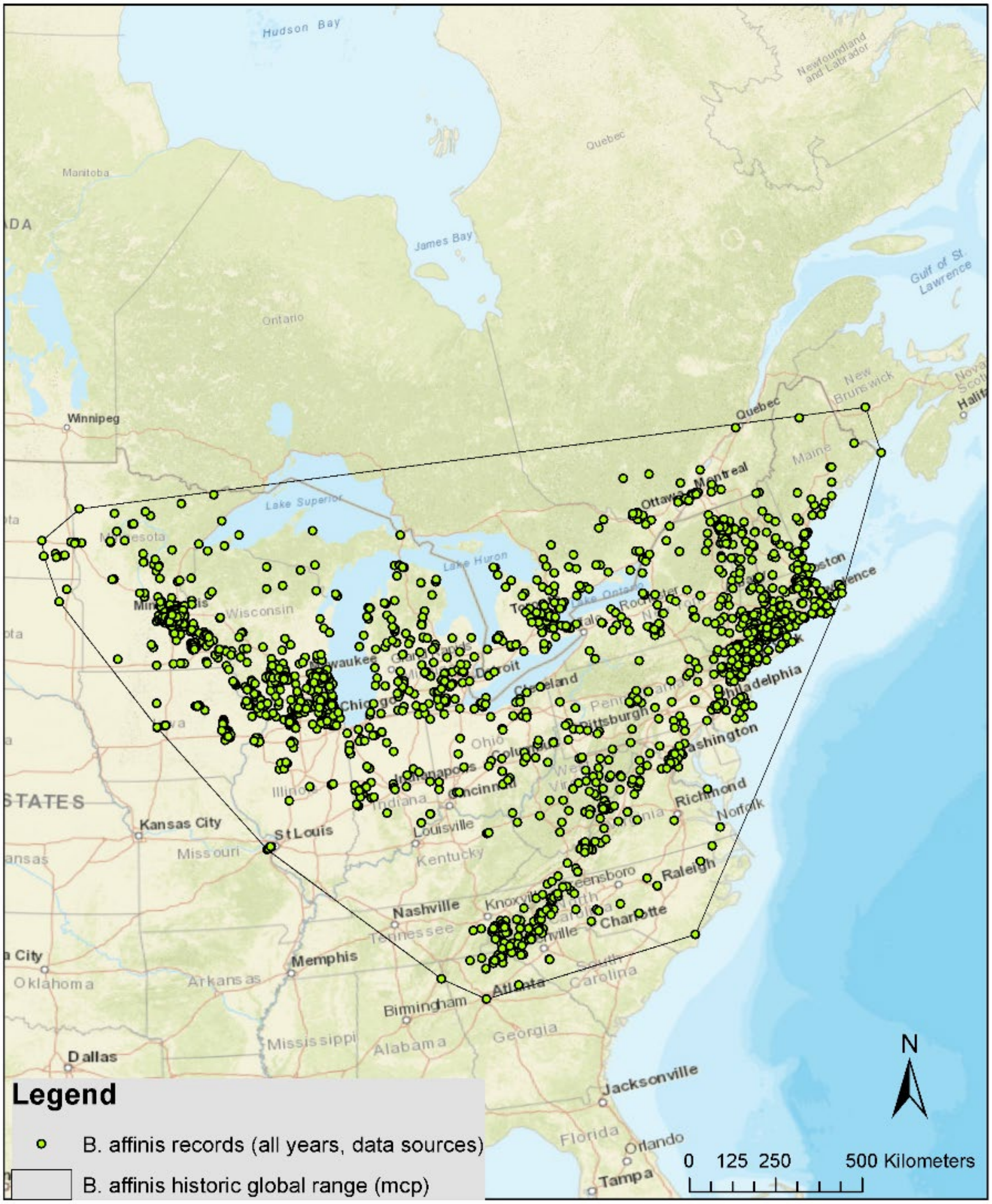

Figure 4. The historical global range of the Rusty-patched Bumble Bee in the United States and Canada, and a minimum convex polygon (mcp) based on records from all years (1881–2020). It includes records from BBNA: Bumble Bees of North America dataset; BBW: Bumble Bee Watch dataset; ECCC: Environment and Climate Change Canada – Quebec dataset; and GBIF: Global Biodiversity Information Facility dataset. Map created by Victoria MacPhail using Canada Albers Equal Area Conic projection.

Canadian Range

The historical Canadian range of this species included southern Ontario, southwestern Quebec, and New Brunswick (Laverty and Harder 1988; COSEWIC 2010; Klymko and Sabine 2015) (Figure 5).

Figure 5. The historical range of the Rusty-patched Bumble Bee in Canada and a minimum convex polygon (mcp; restricted to Canada's terrestrial jurisdiction) based on records from 1912–2009. See Figure 4 and the text for discussion about data sources. The maximum current EOO of 203 km^2 is based on records from Pinery Provincial Park and Manester Tract in Norfolk County, 2000–2009. Map created by Victoria MacPhail using Canada Albers Equal Area Conic projection.

Klymko and Sabine (2015) confirmed the historical presence of this species in New Brunswick, based on a physical specimen currently housed at the New Brunswick Museum (specimen NBM-035767) that was collected in Fredericton, NB. They also noted a record of the species observed in blueberry fields in a report by Boulanger *et al*. (1967). During this review, the presence of a second specimen from New Brunswick was confirmed, a male Rusty-patched Bumble Bee collected from Grand Manan Island on October 10, 1990 (collector unknown). This specimen is currently housed at William Patterson University in New Jersey, with the identification confirmed by John Ascher, Elaine Evans, and Paul Williams via photos of the specimen. Records from adjacent states (e.g., Maine; Figure 4) support the likelihood of this bee's presence in New Brunswick. Two other purported records from New Brunswick, also deemed erroneous in the previous COSEWIC status report (2010), were noted in the preparation of this report but not included in the analyses of geographic range (see Appendix 1 for a discussion).

The Recovery Strategy for the Rusty-patched Bumble Bee (*Bombus affinis*) in Canada (ECCC 2020) indicated that the species' historical range extended from Kenora in northern Ontario (with three occurrences near Kenora and one near White River) east to northern Quebec (near Canton Paradis, Macamic, and Trécesson/La Ferme region). These occurrences were not documented in the previous status report (COSEWIC 2010) or earlier publications such as Laverty and Harder (1988). They were based on incorrect identifications. Two other records from the BBNA database were deemed erroneous. Documentation of each record is included in Appendix 1 to avoid future confusion.

Despite targeted search efforts in Ontario and Quebec and broad bumble bee surveys from Ontario through New Brunswick (see **Search Effort**), no Rusty-patched Bumble Bee specimens were found in Canada from 2010 to 2021.

General methodology notes:

Datasets used and their abbreviations include:

- BBW: Bumble Bee Watch
- BBNA: Bumble Bees of North America
- GBIF: Global Biodiversity Information Facility, all *Bombus* (including records from iNaturalist)
- ECCC (QC): Environment and Climate Change Canada, Quebec dataset (including historical Rusty-patched Bumble Bee records and recent field surveys)
- York University, WPC (not in BBNA): records from York University and Wildlife Preservation Canada not already included in the Bumble Bees of North America
- ACCDC: Atlantic Canada Data Conservation Centre
- Klymko: records from J. Klymko not in the ACDCC database (recent surveys for the Yellow-banded Bumble Bee)

To complete the range maps and to quantify search effort for this report, data were obtained from several sources (see **Authorities Contacted**, **Collections Examined**, and sections above) and then cleaned. As the coordinates for some records were offset for privacy/protection, the actual site may not be exactly as displayed (all but three records were offset < 30 km; the maximum offset distance was 100 km). Records that did not have a date associated with them were still plotted and assumed to be pre-2010. As data are shared among different repositories, duplicates can exist between datasets (e.g., BBNA and GBIF). This does not affect the EOO, but duplicates were removed for other analyses (i.e., search effort section). In total, 42 records of Rusty-patched Bumble Bee and 192 records of other bumble bees appeared to be duplicates since they had the same surveyor, date, place, and species in both the BBNA and GBIF datasets.

Extent of Occurrence and Area of Occupancy

All Rusty-patched Bumble Bee records (1912–2009) were plotted to produce a range map (Figure 5). The area of a minimum convex hull polygon from this map gives the historical EOO in Canada (Ontario, Quebec, and New Brunswick) of approximately 203,494 km^2 (367,784 km^2 including the Great Lakes and adjacent USA).

The historical index of area of occupancy (IAO), 564 km^2, is based on 141 separate 2 km x 2 km grid cells.

Based on the most recent occurrences of Rusty-patched Bumble Bee, EOO (203 km^2) and IAO (16 km^2) were estimated based on three individuals at Pinery Provincial Park (three 2 km by 2 km grid squares) and one individual at St. Williams Conservation Reserve (Manester Tract), in Norfolk County. Given that no individuals have been found in Canada since 2009, the EOO and IAO for 2010 to 2020 are between 0 and 203 km^2 and 0 and 16 km^2 respectively.

Search Effort

Bumble bee collections and surveys have been conducted across Ontario, Quebec, and New Brunswick since at least 1844, with their number increasing through the 1900s and in the last decade (2010–2020) (Figure 6). There are at least 435 records of Rusty-patched Bumble Bee in Ontario: the oldest is August 2, 1912, in Lobo (near London), and the most recent, September 3, 2009, in Pinery Provincial Park (near Grand Bend). There are 159 records of Rusty-patched Bumble Bee in Quebec, the first in 1927 in Sainte-Anne-de-Bellevue and the last in 1996 at Mont Rigaud. There are three credible records of Rusty-patched Bumble Bee in New Brunswick: 1949 in Fredericton, between 1961 and 1965 in a blueberry field in Charlotte County, and 1990 on Grand Manan Island, Charlotte County.

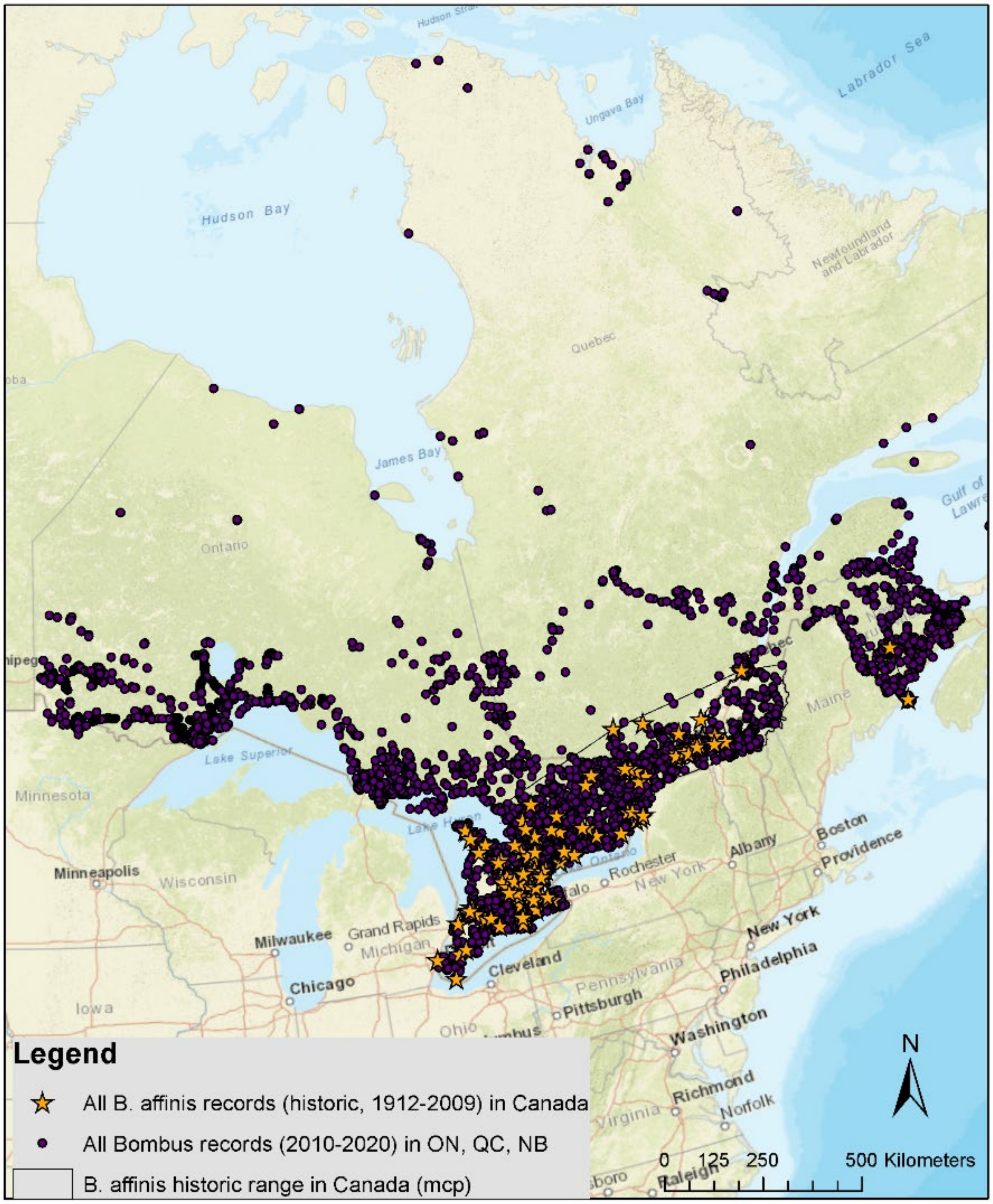

Figure 6. All bumble bee records (purple circles) and historical range of Rusty-patched Bumble Bee (orange stars) in Canada. Rusty-patched Bumble Bee was historically found in the southern portions of Ontario and Quebec, and in western New Brunswick (specific sites orange stars; Canadian range open polygon). It has not been found in the last decade (2010–2020) despite general bumble bee surveys (purple circles) occurring throughout these three provinces. See Table 1 for more details of search effort and the text for a description of the data sources used. Map created by Victoria MacPhail using Canada Albers Equal Area Conic projection.

Table 1. Summary of all bumble bee surveys in 2010–2020 that occurred in Rusty-patched Bumble Bee's historical Canadian range, overall and per province, including earliest and last observation dates, total number of records, unique observation dates, unique surveyors, and unique sites. Bumble Bee Watch and iNaturalist are community science programs based primarily on incidental observations, while other data generally come from more comprehensive surveys. Note that there may be overlap between the datasets for dates, surveyors, and sites, so the total number of community science records is not the difference between "All Data" and "Non-Community Science Data." Prov. = Province; ON = Ontario; QC = Quebec; NB = New Brunswick; Early = Earliest observation date; Late = Latest observation date.

	All Data						Non-Community Science Data					
Prov.	Early date	Late date	# records	# dates[1]	# surveyors[2]	# sites[3]	Early date	Late date	# records	# dates[1]	# surveyors[2]	# sites[3]
ON	March 22	Nov 21	26793	1386	2723	850	April 17	Nov 21	15198	428	137	191
QC	March 1	Oct 31	3782	519	339	242	March 1	Sept 28	2665	121	8	97
NB	April 12	Oct 15	521	165	99	51	May 3	Oct 15	316	44	20	24
All data	March 1	Nov 21	31096	1479	3094	1130	March 1	Nov 21	18179	530	162	312

[1] All records with no specific survey date within a single year were treated as a single unique date,

[2] The number of unique surveyors is approximate and is based on the number of completely identical surveyor names listed. Some surveys conducted by multiple individuals separately (e.g., individual #1, #2, and #3) and by those same individuals combined (#1,2,3); each of these instances would count as a different unique observer (4 unique observers in this example).

[3] The number of sites is approximated based on the number of unique 100 km^2 grids with records.

Search effort since 2010 has been significant. From 2010 to 2020, approximately 31,100 bumble bee records were obtained, representing 1,130 unique 10 x 10 km grids or sites, from across the Rusty-patched Bumble Bee's historical range in Canada (Table 1; hatched area). They represent at least 1,480 unique survey dates by 3,095 unique individual surveyors or surveyor combinations (see Table 1 for comparison without the Bumble Bee Watch and iNaturalist programs). Seasonally, the earliest was observed March 1 and the latest November 21. Rusty-patched Bumble Bee is an early emerging species and one of the latest species active in the autumn (Williams *et al*. 2014). Therefore surveys during the non-winter months have the potential to locate this species. However, the possibility of finding individuals is the greatest in August and September when foraging workers and males are most active away from nests.

Records were separated by province for comparison of search effort. To determine the number of unique sites surveyed, a 10 km x 10 km grid was overlaid over the historical range, and each observation was joined with the corresponding grid ID number in ArcGIS. The 10 km value was based on conservative estimates of bumble bee foraging distance, which are usually less than 5 km (e.g., Dramstad 1996; Osborne *et al*. 1999; Osborne and

Williams 2001; Stout and Goulson 2000; Walther-Hellwig and Frankl 2000a,b; Fijen 2021). The grid system was also used to combine or collapse observations that may have been submitted by different individuals and/or with different site names, in order to minimize repetition.

Ontario was the most heavily surveyed province within the historical Rusty-patched Bumble Bee range (Table 1); it accounted for 86.2% of all observations and 75.2% of all unique sites. Quebec had 12.2% of the observations and 21.4% of the sites, while New Brunswick had 1.7% of the observations and 4.5% of the sites (Table 1). Bumble Bee Watch and iNaturalist contributed, particularly in Ontario where 659 of the 850 sites and 2,586 of the 2,723 surveyors were based only on these programs (Table 1). Sites surveyed by users with these two programs are not likely to have been searched as intensively as the ones where researchers participated, as many community scientists submit few (e.g., <10) individual records in total (MacPhail *et al*. 2020a). However, since many community scientists are particularly "on the lookout for" the Rusty-patched Bumble Bee, there is potential for them to submit photos of this species (MacPhail *et al*. 2020b). Indeed, 725 observations of Rusty-patched Bumble Bee were reported to Bumble Bee Watch from the United States between 2010 and 2020 (MacPhail 2021). Researchers have conducted targeted surveys at all sites where the Rusty-patched Bumble Bee has been found since the mid-1990s. Published reports are not available for many of these surveys. Examples for Ontario include Colla and MacPhail (2014), Gibson *et al*. (2019), and MacPhail *et al*. (2019). Examples for Quebec include Saint-Germain (2017, 2018) and Drapeau Picard (2020a,b). While the Rusty-patched Bumble Bee has not been observed in New Brunswick since 1990, there have been recent surveys (Klymko and Sabine 2015; Brooks and Nocera 2020; NB Natural Resources and Energy Development 2021; see also data in this report).

Null observations (i.e., sites that were surveyed but where no bumble bees were found) are not incorporated into the BBNA or GBIF databases. Therefore, more sites and survey dates exist. Null surveys were included in some datasets, e.g., York University and Wildlife Preservation Canada, and/or were re-incorporated after reviewing the raw data, particularly for Pinery Provincial Park. There were at least 130 surveys that found no bumble bees.

As the Rusty-patched Bumble Bee was last seen in Canada at Pinery Provincial Park in 2005 and 2009, an emphasis was placed on evaluating search effort at that park directly to determine both the comprehensiveness of surveys and the likelihood that the species is still present (Table 2). From 2010 to late August 2020, observations occurred on ~332 unique dates, representing ~2,014 person-hours (Figure 7, Table 2). In total, 3,398 bumble bees, representing 10 unique species plus the categories of "unknown *Bombus*" and "*B. vagans* or *sandersoni* or *perplexus*," were found. Surveys undertaken by community scientists increased the search effort compared to that by bumble bee researchers alone (307 dates versus 25; 1,855 hours (estimated) versus 159; 2,317 bees versus 1,081, 10 +2 species versus 7 +2) (Figure 7, Table 2). Indeed, community scientists provided the only park observations of Northern Amber Bumble Bee, *B. borealis* (1 record), Golden Northern Bumble Bee, *B. fervidus* (1 record), and Red-belted Bumble Bee, *B. rufocinctus* (11 records) in this past decade (2010–2020), and two of the six records of American Bumble

Bee, *B. pensylvanicus*. This underscores the value that these programs can provide in the search for rare or uncommon species.

Table 2. Search effort, including hours spent surveying and bumble bee species found, at Pinery Provincial Park 2010–2020. Data sources investigated included files from the BBNA database, the BBW program, GBIF (including iNaturalist records), Wildlife Preservation Canada, and York University.

Year[1,2]	Date[3]	Observers[4]	Total person-hours	Total # bees	Total #specific species	Total # species, groups	*bimaculatus*	*borealis*	*citrinus*	*fervidus*	*griseocollis*	*impatiens*	*pensylvanicus*	*perplexus*	*rufocinctus*	*vagans*	*vagans, sandersoni or perplexus*	*sp.*
2012	July 12	S. Colla, K. Wazbinski	max 12[5]	10	4	4	x				x	x				x		
2012	Aug 23	S. Colla	max 5.3[5]	2	2	2					x	x						
2013	July 29	S. Colla, M. Cheryomina	uncertain; min 2	31	3	3					x	x				x		
2013	July 29	V. MacPhail	4	2	1	1					x							
2013	July 30	S. Colla, M. Cheryomina	uncertain; min 1	9	2	2						x				x		
2013	July 30	V. MacPhail	7.5	3	2	2						x				x		
2013	August 10 and Aug 26	2 BBW contributors[6]	unknown	2	1	2					x							x
2014	July 10	V. MacPhail, E. Nardone	6.5	45	4	4	x				x	x				x		
2014	Aug 25	V. MacPhail, E. Nardone	7	129	5	5	x		x		x	x				x		
2014	Sept 10	V. MacPhail, E. Nardone, S. Colla	6.42	98	5	5	x		x		x	x				x		
2014	July 18, Aug 06, and 07,	2 BBW contributors[6]	unknown	5	3	3					x	x				x		
2015	June 6	V. MacPhail + 5 volunteers for most of day	21.75	14	2	3	x					x						x
2015	July 25	V. MacPhail, S. Hill	2	21	2	2					x	x						
2015	Sept 24	V. MacPhail, S. Ferguson	8	151	2	2						x				x		
2015	July 03, 08	2 iNaturalist contributors[6]	unknown	3	2	2					x	x						
2015	43 dates: earliest May 23, latest Sept 24	23 BBW contributors [6] (min; including WPC BBW volunteers)	unknown[7]	513	6	8	x		x		x	x			x	x	x	x
2015	various	~42 WPC BBW volunteers	±504	(included in overall BBW records)														
2016	June 12	V. MacPhail, H. Tompkins	2	1	1	1						x						
2016	July 10	V. MacPhail, H. Tompkins	incidental obs.	5	3	3					**x**	**x**				**x**		

Year[1,2]	Date[3]	Observers[4]	Total person-hours	Total # bees	Total #specific species	Total # species, groups	*bimaculatus*	*borealis*	*citrinus*	*fervidus*	*griseocollis*	*impatiens*	*pensylvanicus*	*perplexus*	*rufocinctus*	*vagans*	*vagans, sandersoni or perplexus*	*sp.*
2016	July 10	V. MacPhail, H. Tompkins, plus 7 volunteers for part of day	11	22	2	2			**x**		**x**							
2016	July 11	V. MacPhail, H. Tompkins	6.33	48	5	5	x				x	x				x		
2016	May 26	1 iNaturalist contributor[6]	unknown	1	1	1					x							
2016	25 dates: earliest June 13, latest Aug 22	8 BBW contributors[6] (min; including WPC BBW volunteers)	unknown[7]	106	4	5	x				x	x				x		x
2016	various	WPC BBW volunteers	±217	(included in overall BBW records)														
2017	June 17	S. Gibson	0.5	1	1	1	x											
2017	Aug 23	S. Gibson	1.75	13	4	4			x		x	x				x		
2017	Sept 21	V. MacPhail	7	126	5	5			x		x	x	x	x				
2017	May 19, June 25	2 iNaturalist contributors[6]	unknown	2	2	2	x					x						
2017	22 dates: earliest July 02, latest Aug 06	11 BBW contributors [6] (min; including WPC BBW volunteers)	unknown[7]	318	7	9	x		x		x	x	x		x	x	x	x
2017	various	WPC BBW volunteers	230 (102 training, 128 surveying)	(included in overall BBW records)														
2018	Sept 14	V. MacPhail	6	168	3	3			x			x		x				
2018	11 dates: earliest June 03, latest Sept 28	7 iNaturalist contributors[6]	unknown	13	4	4	x		x		x	x						
2018	25 dates: earliest June 26, latest Sept 05	4 BBW contributors[6] (min; including WPC BBW volunteers)	unknown[7]	614	7	9	x		x		x	x		x	x	x	x	x
2018	min 33 independent surveys	WPC BBW volunteers	min 66; max 264	(included in overall BBW records)														
2019	July 31	V. MacPhail, A. Lavictoire, J. Sanders	19.5	122	4	4	x				x	x				x		
2019	12 dates: earliest May 27, latest Oct 06	9 iNaturalist contributors[6]	unknown	13	4	4	x	x	x		x	x						

Year[1,2]	Date[3]	Observers[4]	Total person-hours	Total # bees	Total #specific species	Total # species, groups	*bimaculatus*	*borealis*	*citrinus*	*fervidus*	*griseocollis*	*impatiens*	*pensylvanicus*	*perplexus*	*rufocinctus*	*vagans*	*vagans, sandersoni or perplexus*	*sp.*
2019	33 dates: earliest May 27, latest Sept 12	5 BBW contributors[6] (min; including WPC BBW volunteers)	unknown[7]	655	9	10	x	x	x	x	x	x	x	x		x		x
2019	min 47 surveys	WPC BBW volunteers	min 94; max 376	(included in overall BBW records)														
2020	June 5	V. MacPhail	7.25	46	3	4	x					x				x		x
2020	July 7	A. Liczner, A. Filazzola	12.37	11	2	2	x					x						
2020	Aug 3	S. Colla	1.78	2	2	2	x				x							
2020	Aug 4	S. Colla	0.62	1	1	1						x						
2020	10 dates: earliest July 02, latest July 27	5 BBW contributors[6] (min; including WPC BBW volunteers)	unknown[7]	68	4	4	x				x	x				x		
2020	July 13, 14, Aug 17	2 iNaturalist contributors[6]	unknown	4	3	3	x				x	x						
2020	min 33 surveys	WPC BBW volunteers	min 66; max 264	(included in overall BBW records)														
Total combined	**~332 unique dates**		**~2014 hours**	**3398 bees**	**10 unique species**	**12 species, groups**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Total researcher	**25 dates**		**159**	**1081**	**7**	**8**	**x**		**x**		**x**	**x**	**x**	**x**		**x**		**x**
Total iNat, BBW	**307 dates**		**1855**	**2317**	**10**	**12**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**

[1] Note that this table excludes surveys undertaken at adjacent sites, like Camp Attawandaron and private homes, and nearby sites, like Karner Blue Sanctuary.

[2] For 2020, observations were only up to mid/late August; it is anticipated that additional limited search effort will occur through the remainder of August and September and additional community science observations will be verified/reach research grade.

[3] For volunteers with the iNaturalist and BBW program, this excludes dates when surveys occurred, but no bumble bees were observed

[4] WPC BBW volunteers = volunteers with the formal BBW community science program run through Wildlife Preservation Canada (versus incidental observations by members of the public to the Bumble Bee Watch program)

[5] Includes travel time between sites, search time, processing time, etc., but not lunch.

[6] For incidental observations reported to the BBW program and to iNaturalist, it is not known how much time was spent surveying, whether other *Bombus* were observed, or whether other individuals assisted in the surveys.

[7] But see main entry for WPC BBW volunteers for minimum number of hours, since total observations added to the BBW dataset surpassed those collected during the WPC formal BBW survey program.

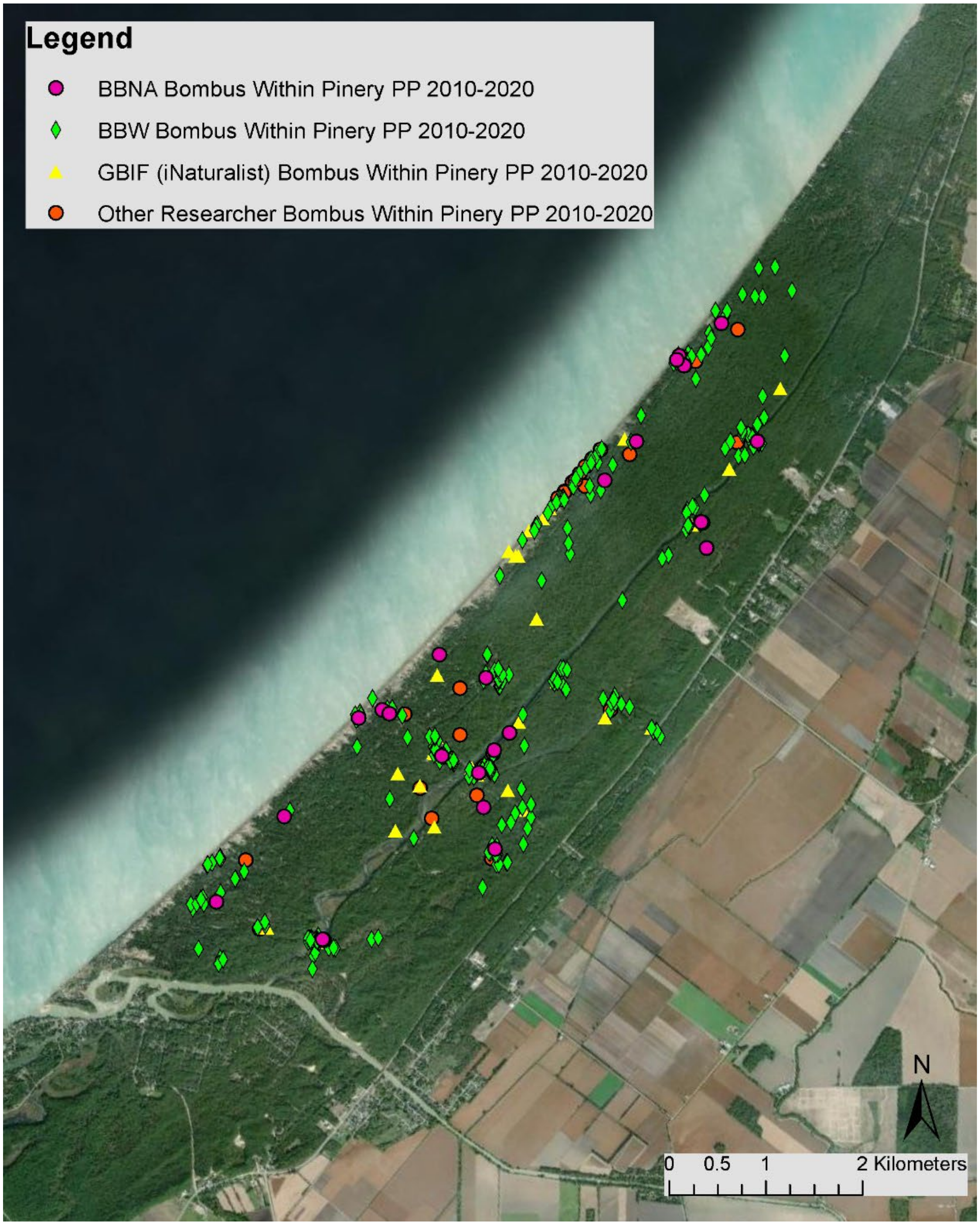

Figure 7. Sites where bumble bee search effort has occurred at Pinery Provincial Park in Ontario since 2010. No records of Rusty-patched Bumble Bee were obtained despite the geographic and temporal coverage. Abbreviations: BBW (green diamonds): Bumble Bee Watch dataset; BBNA (purple circles): Bumble Bees of North America dataset; GBIF (yellow triangles): Global Biodiversity Information Facility dataset; Other Researchers (red circles): records from York University and Wildlife Preservation Canada not already included in the Bumble Bees of North America dataset. Map created by Victoria MacPhail using Canada Albers Equal Area Conic projection. Underlying photo layer credits: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Other sites that potentially could support the Rusty-patched Bumble Bee, in Ontario (Norfolk County and Frontenac Axis), southern Quebec, and western New Brunswick, have fewer focused surveys.

Rare or uncommon bumble bees can be difficult to locate, despite extensive surveys. For example, of 365 *Bombus* records from 1977 through 2009 in Pinery Provincial Park, Black-and-Gold Bumble Bee, *B. auricomus* (1 record), Gypsy Cuckoo Bumble Bee (8 records), and Indiscriminate Cuckoo Bumble Bee, *B. insularis* (2 records) were observed prior to 2010, but not after 2010. The reverse is also true. American Bumble Bee (6 records) and Red-belted Bumble Bee (1 record) were not seen prior to 2010 but have been observed in the last decade (2010–2020). This suggests that it is possible for species with low numbers to still occur in the park or to colonize it from nearby areas.

Various groups continue to conduct bumble bee research and community science observations throughout Ontario, Quebec, and New Brunswick. Almost 8,000 *Bombus* observations were uploaded to iNaturalist from Ontario, Quebec, and New Brunswick in 2021. Search effort for the Rusty-patched Bumble Bee across its historical range is higher than reported here and continues. Due to the species' rarity and community awareness , any observation of Rusty-patched Bumble Bee would likely be shared.

It is also useful to consider observations of Rusty-patched Bumble Bee in the USA. Since 2000, about 1,600 observations have been recorded in iNaturalist. Most are from Minnesota, Iowa, and Indiana and, more recently, from Virginia and West Virginia. More than 100,000 bumble bee observations have been recorded in the historical range of the Rusty-patched Bumble Bee since 2000. In Maine, New Hampshire, Vermont, New York, and Michigan, there have been no observations since 2000. There is one observation from Ohio in 2000.

HABITAT

Habitat Requirements

The Rusty-patched Bumble Bee is a generalist that is found in a variety of landscapes including wooded areas, upland forests, oak savannah, remnant and restored tallgrass prairie, wetlands, open fields, and agricultural, and urban areas (Colla and Dumesh 2010; Williams *et al.* 2014; Dolan *et al.* 2020; ECCC 2020). In Canada, it has been found in the Great Lakes Plain and Atlantic Maritime Ecozones (COSEWIC 2018).

Like all bumble bees, the Rusty-patched Bumble Bee requires floral, nesting, and overwintering resources. The species has a long colony cycle, which extends from April to October, and requires flowering plants throughout this period to support colony growth and the production of males and gynes in late summer or fall. It is thought that colony size and resource availability are the signals that cause the colony to switch from producing workers to producing reproductive individuals (gynes and males) (Goulson 2003).

Given the long active season, many different plants are exploited to obtain nectar and pollen. For lists of plant species on which the Rusty-patched Bumble Bee forages, see Colla and Dumesh (2010), Dolan *et al.* (2020), Simanonok *et al.* (2020), and MacPhail (2021).

The Rusty-patched Bumble Bee nests underground in abandoned small mammal burrows (Macfarlane 1974; Laverty and Harder 1988) and may also nest in hollow stumps or logs (Macfarlane 1974). Some bumble bees nest above ground (Liczner *et al.* 2019). Bumble bee nesting habitat requirements are not well understood for any species. Rusty-patched Bumble Bee nests may be more common in wooded areas with entrances covered by leaf litter (Plath 1922, 1927).

Bumble bee queens overwinter underground, usually in north-facing areas that are shaded and well-drained , with loose soil and fallen dead wood (Liczner and Colla 2019; ECCC 2020).

Habitat Trends

Ongoing and historical development in the Rusty-Patched Bumble Bee's Canadian range have caused major landcover changes, primarily through agricultural intensification and urbanization. Pindar *et al*. (2017) and Hogg and Jones (2018) provide high level reviews of pollinator resources across southern Ontario aimed at practical pollinator conservation.

The Mixedwood Plains Ecozone (about 73% of which is in southern Ontario and the rest in Quebec) contains about 92% of Ontario's human population, and has been heavily impacted by humans, with 68% of the land covered by anthropogenic land use types, particularly agricultural (Ontario Biodiversity Council 2010, 2011; Statistics Canada 2016). This has resulted in threats, including habitat loss, invasive alien species, human population growth, pollution, unsustainable land use, and climate change (Ontario Biodiversity Council 2010, 2011; ESTR Secretariat 2016).

Habitat changes are ongoing. For example, the area of land in crops in Lambton County (includes Pinery Provincial Park, where the last known sighting of Rusty-patched Bumble Bee occurred) increased by 1.0% from 207,621 ha in 2011 to 209,910 ha in 2016 (Statistics Canada 2021), while in Norfolk County (includes St. Williams Conservation Reserve, where the second most recent sighting of the bee was made), the crop area increased by 1.1% from 35,350,270 ha to 37,790,608 ha. The area of woodlands and wetlands decreased by 0.3% from 19,211 ha to 18,736 ha in Lambton County and by 0.06% from 4,897,367 ha to 4,620,490 ha in Norfolk County during the same period (Statistics Canada 2021).

Urban and agricultural areas often have limited floral resources or may not provide enough floral resources throughout the entire colony cycle (Cameron and Sadd 2020). Additionally, urban and agricultural areas may have limited nesting and overwintering sites because of increases in impermeable surfaces and soil disturbance due to the construction of roads and buildings, soil tilling, and harvesting practices (Cameron and Sadd 2020). Intensifying agricultural areas may also expose the Rusty-patched Bumble Bee to insecticides and pathogens from managed bees used for crop pollination (Cameron and Sadd 2020). In cities, increased interest in urban beekeeping may also increase pathogen exposure and further reduce nectar and pollen availability through increased competition (Colla and MacIvor 2017). For example, the City of Toronto went from 221 registered Western Honey Bee hives in 2015 to 834 registered hives in 2018 (Kozak pers. comm. 2019).

Recent research on Rusty-patched Bumble Bee habitat suggests that early spring flowering plant species in forests are declining, while the abundance of later season forage species has not changed in grasslands and wetlands (Mola *et al.* 2021a). Declines in spring forest flowers may cause slow growth of colonies because spring queens preferentially forage in woodlands (Mola *et al*. 2021a,b). As previously mentioned, early spring forage may be particularly important for ensuring colony success (Carvell *et al.* 2017). Recent analysis of pollen found on museum specimens of Rusty-patched Bumble Bee suggests that there has been little change between historical and current forage species (Simanonok *et al*. 2020). These authors suggest that the loss of preferred forage species has not been a major contributor to declines in the Rusty-patched Bumble Bee.

Climate change will continue to impact habitat suitability for bumble bees including the Rusty-patched Bumble Bee (Kerr *et al*. 2015; Soroye *et al*. 2020). An increase in extreme weather events can impact colony success by directly affecting nest sites (i.e., flooding) and by limiting forage availability (i.e., spring frosts, droughts) (Bush and Lemmen 2019). Continued warming is expected to result in reductions in the range of many bumble bee species through direct effects (i.e., extreme events including heat waves) and indirect effects (i.e., decrease in floral resources as described above) (Cameron and Sadd 2020).

Within the last 10 years, Pinery Provincial Park has undertaken rehabilitation and restoration projects that should increase the amount of suitable habitat for the Rusty-patched Bumble Bee. These include closing sections of campground to allow naturalization, removal of invasive pines, prescribed burns, deer management to preserve oak savannah habitat, and dune rehabilitation. These habitat restoration projects should increase the available foraging, nesting, and overwintering habitat in the park.

BIOLOGY

The Rusty-patched Bumble Bee shares life history traits with other bumble bees and particularly with other members of the subgenus (*Bombus s.s*.). Good summaries of general bumble bee biology include Alford (1975), Laverty and Harder (1988), Goulson (2003), Benton (2006), and Williams *et al*. (2014), upon which the following text is based.

Life Cycle and Reproduction

Like most bumble bees, the Rusty-patched Bumble Bee is a eusocial species which has a one-year colony cycle (i.e., generation time = one year). In the spring, foundress queens search for a suitable nest site, establish a nest, then lay eggs that develop into female workers. Workers take over the foraging and nesting duties for the colony while the queen stays in the nest to lay eggs. The colony grows throughout the summer as the number of workers increases. During this time, cuckoo bumble bees may come in and usurp the nest and lay eggs which the workers of the host colony tend until adulthood. Later in the summer and into early fall, when the colony is at peak size, males and gynes (unmated, large females) begin to be produced. These females leave the colony to mate. Mated females spend the winter underground in diapause. Males and workers die before winter. The queens thus live approximately one year but all other colony members live for only a few weeks.

Given its small population size in Canada, the Rusty-patched Bumble Bee may be vulnerable to genetic drift (resulting in the loss of genetic diversity) and inbreeding which may make it more vulnerable to pathogens or other stressors. Because of the haplodiploid sex determination system of bees, inbreeding can lead to the production of sterile, diploid males instead of fertile females. Thus, as smaller populations become less genetically diverse and more homozygous, they will produce fewer and fewer fertile females, causing a further reduction in population size (Zayed and Packer 2005)

Physiology, Adaptability, and other Characteristics

Bumble bees thermoregulate, keeping their body temperatures and nests above ambient air temperatures (Heinrich 2004). This is particularly important in temperate regions like southern Ontario, and for species like the Rusty-patched Bumble Bee that have long colony cycles extending from the spring to autumn (Macfarlane 1974).

The Rusty-patched Bumble Bee has been successfully reared in captivity (Macfarlane 1974; Fisher 1984; Gegear and Laverty pers. comm. in COSEWIC 2010). As such, it is a good candidate for *ex situ* conservation work and scientific study if queens or nests can be located.

Dispersal and Migration

The dispersal capability of the Rusty-patched Bumble Bee is unknown. Dispersal has been studied in the closely related European Buff-tailed Bumble Bee (*Bombus terrestris*) (Walther-Hellwig *et al*. 2000a,b; Chapman *et al.* 2003; Kraus *et al.* 2009). The Buff-tailed Bumble Bee introduced into Tasmania expanded its range at a rate of approximately 10 km/year (Stout and Goulson 2000). However, Fijen (2021) suggests that individuals may migrate hundreds of kilometres. The 10 km/year dispersal rate for the Buff-tailed Bumble Bee is the dispersal distance assumed for bumble bees. However, given the lack of recent detection of Rusty-patched Bumble Bees in Canada, comparisons with successful, invasive and/or common species might be inappropriate. The Rusty-patched Bumble Bee is nonmigratory.

Interspecific Interactions

As a flower-visiting insect, the Rusty-patched Bumble Bee interacts primarily with plants, in some cases providing pollination services. This species is a short-tongued, generalist forager. Macfarlane (1974) documented more than 50 genera of flowers used by the Rusty-patched-Bumble Bee in Ontario. Across the range in the USA, Simanonok *et al*. (2021) found pollen from almost 100 taxa across 100 years. While Asteraceae are consistently the plants visited most often, a diversity of flowering plant species including willows, clovers, and vetches are regularly used (MacFarlane 1974; Colla and Dumesh 2010; Simanonok *et al*. 2021). Forage plants may be limiting for colony growth, particularly in the spring when the queens need to replenish their energy stores or in the fall before they go into diapause. Bumble bee colonies require abundant and diverse pollen sources throughout their colony cycle in order to produce males and gynes.

The Rusty-patched Bumble Bee has evolved a somewhat uncommon foraging behaviour called 'nectar-robbing' (Rust 1979). They can pierce the corolla of a long-tubed flower (e.g., Spotted Jewelweed, *Impatiens capensis*) to access the nectar directly. This behaviour bypasses the reproductive structures and thus does not aid in pollination.

This bumble bee is a host to at least one socially parasitic bumble bee, Gypsy Cuckoo Bumble Bee (*Bombus bohemicus,* formerly *B. ashtoni*) (Plath 1934; Fisher 1984). This species is listed as Endangered (SARA, Schedule 1) (COSEWIC 2014).

Many bumble bee pathogens and parasites have been detected in North America, including *Crithidia* spp. (Trypanosomatida), the microsporidian *Vairimorpha bombi* (Tokarev *et al*. 2020), *Apicystis bombi* (Neogregarinorida), *Sphaerularia bombi* (Nematoda), tracheal mites, and viruses (Macfarlane 1974; Colla *et al*. 2006; Kissinger *et al*. 2011; Tripodi *et al.* 2018). In Canada, pathogen screening was not conducted during the period when Rusty-patched Bumble Bees were more numerous, and so it is unclear which pathogens co-occurred. The threats section has more information. Various parasitoids, including phorid and conopid flies, are known to attack wild bumble bees (Macfarlane 1974; Otterstatter *et al*. 2002; Plischuk *et al*. 2017).

In areas with limited forage resources, introduced competitors such as the Western Honey Bee (*Apis mellifera*) may create additional stress (e.g., Thomson 2004, 2016). Naturally co-occurring, successful bee species such as the Common Eastern Bumble Bee or the Large Carpenter Bee (*Xylocopa virginica*) could compete with the Rusty-patched Bumble Bee for nesting and/or forage resources.

Predators of individual bumble bees include spiders, robber flies, philanthine wasps, and birds (Goulson 2003; Dawson and Chittka 2014; Colla pers. obs. 2020). Cats have injured bumble bees (Colla pers. obs. 2020). Colony predators of bumble bees include wax moths, ants, skunks, foxes, moles, weasels, voles, mink, mice, raccoons, and bears (Goulson 2003).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Bumble bees have been the focus of study in North America for more than a century. However, their colonial nature and a lack of systematic surveys make it challenging to interpret the data.

Surveys have been primarily haphazard and/or opportunistic. The Bumble Bees of North America (BBNA) dataset has compiled an impressive number of records (over 600,000) from researchers and collections as well as from the historical literature (Richardson pers. comm. 2020). However, these data have their limitations given they have been compiled from hundreds of different sources, are based on a variety of survey methods, and do not capture absences or search effort. It is therefore difficult to report abundances. Researchers often report declines in relative abundance instead of absolute abundance (e.g., COSEWIC 2019). Also, the number of queens or active nests is a good estimator of number of mature individuals. However, once a nest is established, queens do not leave the nest. Most surveys focus on workers because they are active outside the nest during the summer and they are more numerous than queens.

Bumble bees are often collected using nets (active collecting) and pinned for identification. Other modes of collection include blue vane traps, Malaise traps, and pan traps. These passive traps sometimes require more processing, as the various solutions (e.g., soapy water, propylene glycol, alcohol) used in the trap may make species identification more challenging due to hair matting. Given the protected status of this species, lethal trapping is not encouraged. Strange and Tipodi (2019) review methods and provide a link to the current literature of survey protocols.

Community science programs, which use photographs to document bumble bees and allow knowledgeable naturalists to corroborate identifications, have contributed to an increase in bumble bee observations in the past 10 years (MacPhail *et al*. 2020a,b, 2021). Some bumble bees are challenging to identify from photos, but males and workers of Rusty-patched Bumble Bee have a distinctive rusty brown patch of hairs surrounded by yellow hairs on the second terga of the abdomen. Community science and photography may be an especially beneficial way of collecting data for this species since there are so few individuals and lethal collection is not allowed.

Detection dogs and molecular methods could be important methods for improving survey effort for Rusty-patched Bumble Bee in the future. Detection dogs have successfully been used to locate bumble bee nests in the UK (Waters *et al*. 2011; O'Connor *et al*. 2012; Liczner *et al.* 2021). Using molecular methods to determine nest site density and relatedness between colonies in an area may also be an option for more accurate counts (e.g., Knight *et al*. 2005; Geib *et al*. 2015).

Abundance

Recent search effort, from 2010 to 2020, in the historical Canadian range of the Rusty-patched Bumble Bee has not located any Rusty-patched Bumble Bees (Table 1; **Search Effort**). More than 31,096 bumble bee records collected at 1,130 sites are included in the 2010–2020 dataset, including both Pinery Provincial Park and St. Williams Conservation Reserve, the sites of the two most recent observations in Canada. Thus, this species has declined in abundance to the point of possible extirpation.

Fluctuations and Trends

Previous work on the Rusty-patched Bumble Bee primarily used relative abundance, the relative proportion of Rusty-patched Bumble Bees among all bumble bees observed, and presence/absence at historical sites to infer declines (Colla and Packer 2008; Cameron *et al.* 2011; Colla *et al*. 2012). Since COSEWIC (2010), there have been additional studies documenting the decline of the Rusty-patched Bumble Bee. All studies which have examined trends in relative abundance and range among bumble bees within the range of Rusty-patched Bumble Bee have found declines.

The Rusty-patched Bumble Bee persists in parts of Minnesota, in low numbers, including the city of Minneapolis (Evans pers. comm. 2020). This may be a key stable subpopulation. The US Fish and Wildlife Service and IUCN Captive Breeding group are collaborating with the Minneapolis Zoo to determine whether captive breeding is feasible and where potential reintroduction sites could be (USFWS 2020).

Cameron *et al*. (2011) surveyed parts of the USA range from 2007 to 2009 and determined that the Rusty-patched Bumble Bee had declined by over 95% in relative abundance and that its range had contracted to approximately 87% of its historical size. The same study found that declining bumble bee species had higher levels of *Vairimorpha bombi* (as *Nosema bombi*) (a microsporidian affecting bumble bees) than the more common species; however, the Rusty-patched Bumble Bee was too rare to include in their analysis.

Using 50 x 50 km grid cells that were sampled from 1964 to 1990 and again 1991 to 2009, Colla *et al.* (2012) showed that the Rusty-patched Bumble Bee persisted in less than 30% of its northeastern North American range. Ten of 21 species experienced declines.

Bartomeus *et al*. (2013) confirmed declines of at-risk bumble bees in the northeastern USA including Rusty-patched Bumble Bee, which they noted had “rapid and recent population loss” based on changes in relative abundance and presence/absence. This was based on a 140-year dataset of 187 bee species, including nine bumble bees.

McFarland *et al*. (2015) document the shift from Rusty-patched Bumble Bee being relatively common in the state of Vermont (8.5% of bumble bees from 1915 to 2011) to possibly extirpated. Despite intensive search effort for more than a decade through the Vermont Bumble Bee Survey, the last record of the species in the state was in 1999(McFarland *et al*. 2015). Rowe *et al.* (2019) indicated that the Rusty-patched Bumble Bee as being historically common in the lower peninsula of Michigan state but that the most recent records (1999) were from a single county.

The IUCN Red List assessment showed that the species' current range was 55% of its historical range; its persistence relative to historical occupancy was 29.77%; and current relative abundance was 7% of historical values (Hatfield *et al*. 2015). However, these declines may be underestimated, as many historical sites were not resurveyed.

There is no evidence that the Rusty-patched Bumble Bee exhibits extreme fluctuations in abundance from year to year.

Rescue Effect

Most recent US records of Rusty-patched Bumble Bee are from Wisconsin and Minnesota (the closest records in Wisconsin are approximately 300 km away from the southern Ontario border). The dispersal ability of the Rusty-patched Bumble Bee is unknown, although related species of bumble bees have dispersal rates of about 10 km/year (Walther-Hellwig *et al*. 2000a,b; Chapman *et al*. 2003; Kraus *et al*. 2009). The rarity of the Rusty-patched Bumble Bee coupled with its likely low dispersal capacity (because its true dispersal rate is unknown) and the extent of habitat modification throughout its range makes it unlikely that the Canadian subpopulations of Rusty-patched Bumble Bee will rebound without human intervention. Given that the Rusty-patched Bumble Bee has been successfully reared in captivity (e.g., Thomson *et al*. 1987), *ex situ* conservation actions are being considered in the USA (USFWS 2020).

THREATS AND LIMITING FACTORS

Threats

The International Union for the Conservation of Nature – Conservation Measures Partnership (IUCN-CMP) threats calculator (IUCN-CMP 2006; Salafsky *et al*. 2008) from the recent Recovery Strategy for the Rusty-patched Bumble Bee (ECCC 2020) was used (see Table 3). Taking into account the recent threats calculator and the fact that no observations of Rusty-patched Bumble Bee have been recorded since 2009, a threats classification and calculator was not completed. For most of the threats discussed below, "timing" is ranked as high, because if Rusty-patched Bumble Bees were present in southern Canada, they would be exposed to these threats currently and into the future. Scope and severity as reported are speculative as current subpopulation size and sites are unknown. The focus is on threats across the potential range in southern Ontario, Quebec, and New Brunswick, rather than threats at the sites where Rusty-patched Bumble Bee was most recently been recorded. This makes it problematic to estimate percent decline. Two threats (1.2 and 5.3) not included in the recovery strategy are dealt with in the text below. Threats are listed below according to their level of impact, from highest to lowest.

Table 3. Threat assessment table from the 2020 Rusty-patched Bumble Bee Recovery Strategy (ECCC 2020). Threat 1.2 "Commercial and industrial areas" and Threat 5.3: "Logging and wood harvesting' were not included in ECCC (2020) but are included in this report.

Threat	Threat Description	Impact [a]	Scope [b]	Severity [c]	Timing [d]	Threat Details
1	Residential and commercial development					
1.1	Housing and urban areas	High – Low	Large – Restricted (11–70%)	Serious – Slight (1–70%)	High	Urban and suburban development
2	Agriculture and aquaculture					
2.1	Annual and perennial non-timber crops	High – Low	Large – Restricted (11–70%)	Extreme – moderate (11–100%)	High	Intensive agriculture
2.3	Livestock farming and ranching	Low	Restricted – Small (1–30%)	Moderate – Slight (1–30%)	High	Livestock grazing
4	Transportation and service corridors					
4.1	Roads and railroads	High – Low	Pervasive – Large (31–100%)	Serious – Slight (1–70%)	High	Road network development
7	Natural system modifications					
7.1	Fire and fire suppression	Low	Restricted – Small (1–30%)	Moderate – Slight (1–30%)	Moderate – Insignificant/Negligible	Fire suppression
8	Invasive and other problematic species and genes					
8.1	Invasive non-native/alien species	Very High – Medium	Pervasive – Large (31 – 100%)	Extreme – Moderate (11–100%)	High	Pathogen transmission and spillover
8.1 and 8.2	Invasive non-native/alien species	Medium – Low	Large – Restricted (11–70%)	Moderate – Slight (1–30%)	High	Competition with honey bees and native bumble bees introduced for commercial purposes
9	Pollution					

Threat	Threat Description	Impact [a]	Scope [b]	Severity [c]	Timing [d]	Threat Details
9.3	Agricultural and forestry effluents	Very High – Medium	Pervasive – Large (31–100%)	Extreme – Moderate (11–100%)	High	Pesticide use
11	Climate change and severe weather	High – Medium	Pervasive – Large (31–100%)	Serious – Moderate (11–70%)	High	

[a] Impact – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each stress is based on the Severity and Scope ratings and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% decline), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown). Not Calculated: impact not calculated as threat is outside the assessment time frame (e.g., timing is insignificant/negligible or low as threat is only considered to be in the past). Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[b] Scope – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[c] Severity – Severity – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or 3-generation time frame. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible = < 1%; Neutral or Potential Benefit = ≥ 0%).

[d] Timing – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

Threat 8: Invasive and other problematic species and genes (very high to medium impact)

Threat 8.1: Invasive non-native/alien species/diseases (very high to medium impact)

Pathogen spillover from managed bee species (which can be native or non-native species) has been linked to the declines in many bumble bee species (Colla *et al.* 2006; Otterstatter and Thomson 2008; Szabo *et al.* 2012; Graystock *et al.* 2016; Cameron and Sadd 2020). Pathogen spillover occurs when infections spread from infected managed species to wild populations. Managed bees have higher pathogen loads than wild bee species (Goka *et al.* 2000; Whittington and Winston 2003; Niwa *et al.* 2004; Colla *et al*. 2006). Managed bees include bumble bees (Common Eastern Bumble Bee) used for pollinating greenhouse vegetables or field fruit crops (e.g., Stubbs and Drummond 2001), and Western Honey Bee. Accidental release of managed bees from greenhouses, or the use of managed bees in a field setting, can cause pathogen spillover into natural areas, or when infected managed bee species forage on the same flowers as wild bees (Goka *et al.* 2000, 2006; Colla *et al*. 2006; Graystock *et al.* 2015). These pathogens, of which there are many, include *Crithidia bombi, Vairimorpha bombi, Apicystis bombi,* and viruses. Declining bumble bee species often have higher pathogen loads than other co-occurring species that are not in decline (Cameron *et al.* 2011). Pathogen spillover is a very high impact threat to the Rusty-patched Bumble Bee which is likely ongoing and still spreading (Otterstatter and Thomson 2008; Ruiz-Gonzalez *et al.* 2012; Schmid-Hempel *et al.* 2014; Graystock *et al.* 2016; Cameron and Sadd 2020). This threat is increasing in part due to the lack of regulations governing the movement of commercial bees between jurisdictions. Additional efforts to reduce the movement of commercial or managed bees between regions, and/or increased screening of managed and commercial bees are needed to reduce the threat of pathogens and prevent additional spread.

Threats 8.1 and 8.2: Problematic native species/diseases (medium to low impact)

Native bee species may experience increased competition for floral resources from the non-native Western Honey Bee (Thomson *et al.* 2016). Western Honey Bee colonies produce many more workers than bumble bee colonies, which could give them an advantage in exploiting nectar and pollen resources, and they can recruit worker bees to flower patches. Honey bees have been shown to competitively exclude bumble bees from flower patches (Walther-Hellwig *et al.* 2006). This was scored under Threat 8.2 in the recovery strategy because of the potential for managed bumble bees to be competitors with wild bumble bees and overlaps with 8.1. Competition for floral resources is a low to medium impact threat to the Rusty-patched Bumble Bee.

<u>Threat 9: Pollution (very high to medium impact)</u>

Threat 9.3: Agricultural and forestry effluents (very high to medium impact)

Agricultural inputs including insecticides, herbicides, and fungicides have been reported to have lethal and sublethal effects on bumble bees. A thorough review of the threats to the Rusty-patched Bumble Bee is included in the recovery strategy (ECCC 2020). A particular category of insecticides, neonicotinoids, have adverse effects on bumble bees, and these chemicals can persist beyond arable lands through runoff and spraying of adjacent non-crop plants (Cameron and Sadd 2020). This class of pesticides impacts invertebrates' memory, learning, and flight behaviour by acting on the acetylcholine receptor in the mushroom body of invertebrate nervous systems (Zars 2000; Simon-Delso *et al.* 2015; Moffat *et al.* 2016). Compared to other bees, bumble bees that were exposed to neonicotinoids flew faster but shorter distances and durations (Kenna *et al.* 2019), made more errors and took longer to complete a maze after a training period (Samuelson *et al.* 2016), took longer to learn how to extract nectar/pollen from flowers (Stanley and Raine 2016), and took longer to forage and returned with less pollen (Stanley *et al*. 2016). Recent research suggests that herbicides, insecticides, and fungicides present in soils in agricultural regions could expose hibernating queens to low and moderate levels of pesticide residue (Rondeau and Raine 2020). Most studies of agricultural inputs look at the effects of a single insecticide, herbicide, or fungicide, but bumble bees are likely exposed to multiple chemicals and stressors simultaneously, which can compound the negative impacts (Tsvetkov *et al.* 2017; Botías *et al.* 2021).

Canada has committed to limiting the use of neonicotinoids to avoid direct exposure of foraging pollinators to these pesticides. Health Canada's Pest Management Regulatory Agency has released recent updates for clothianidin and thiamethoxam (Health Canada 2020) as well as for imidacloprid (Health Canada 2021). These special review decisions restrict the use of these products on additional crops, reduce the allowed treatment rate and number of applications, and introduce new or revised spray buffer zones (Health Canada 2020). The labels on these products (and their use) must be changed within 24 months of the publication date of the decisions.

It is unknown whether Pinery Provincial Park is contaminated with insecticide effluents.

Threat 11: Climate change and severe weather (high to medium impact)

Climate change can have direct and indirect negative effects on bumble bees, which are adapted to cooler conditions including temperate, alpine, and arctic regions. Warming temperatures and changes in precipitation patterns have already caused bumble bee range losses (Biella *et al*. 2017; Soroye *et al*. 2020) and these trends are expected to continue. Extreme climate events including heat waves, droughts, spring flooding, and spring frosts are predicted to become more frequent and more severe with climate change (Easterling *et al*. 2000), and these extreme events will have negative impacts on bumble bees. Climate change will have indirect effects on bumble bees by influencing the availability of foraging resources. These changes can result in increases in forage (with increasing precipitation) or decreases in forage (with droughts or spring frosts). Climate change may also be lengthening the growing season but will not lengthen the bloom period of flowering plant species. This can lead to periods of low floral abundance that can reduce bumble bee colony growth rates (Ogilvie *et al*. 2017). These indirect effects of climate change on the Rusty-patched Bumble Bee were not extensively reviewed in the recovery strategy (ECCC 2020).

Bumble bees are unlikely to be able to expand their range through dispersal to track their shifting climate envelopes. Maximum dispersal distance is approximately 10 km/year (Stout and Goulson 2000). Assuming all species can and would disperse at this rate, most bumble bee species will still experience range loss with ongoing climate change (Sirois-Delisle and Kerr 2018). Additionally, this dispersal rate may be an overestimate of dispersal ability for most bumble bees (Walther-Hellwig and Frankl 2000a; Knight *et al*. 2005). The limited ability of the Rusty-patched Bumble Bee to track changing climatic conditions demonstrates the threat of climate change for this species.

Brinker *et al.* (2018) included the Rusty-patched Bumble Bee in a suite of 280 species which it used to calculate a vulnerability index score using NatureServe's Climate Change Vulnerability Index (CCVI). Their analysis focused on temperature, moisture, perceived sensitivity, and adaptive capacity. The Rusty-patched Bumble Bee came out in the "less vulnerable" category.

Threat 2: Agriculture and aquaculture (high to low impact)

Threat 2.1: Annual and perennial non-timber crops (high to low impact)

Agricultural areas can have limited floral resources available for bumble bees, and/or they may not offer a consistent supply of floral resources throughout the colony cycle. Crops may provide brief and abundant food sources for bumble bees (Kallioniemi *et al.* 2017; Pfeiffer *et al*. 2019); however, bumble bees require abundant flowering resources for the entire colony cycle (spring to fall). A decline in the availability of forage resources at any point in the colony cycle can reduce the survival of colonies and their ability to produce males and queens. Habitat loss through agricultural expansion is often cited as one of the main causes of bumble bee declines (Goulson *et al.* 2008; Grixti *et al.* 2009). Agricultural practices may also reduce nesting habitat for bumble bees, particularly those that involve soil disturbance such as tilling (Rao and Skyrm 2013). Providing areas of semi-natural habitat (e.g., forest or meadow patches, planting wildflower strips, adding hedgerows) may ameliorate the negative effects of agricultural practices on bumble bees (Carvell *et al*. 2015).

Threat 2.3 Livestock farming and ranching (low impact)

Livestock grazing can have a negative impact on bumble bees by reducing the amount of forage available. In addition, nests (particularly surface nests) could be trampled by the livestock (Sugden 1985; Jepsen *et al*. 2013). Low level grazing could increase flower availability.

Threat 1: Residential and commercial development (high to low impact)

Threat 1.1 Housing and urban development (high to low impact)

The Rusty-patched Bumble Bee has occurred in some of the most urbanized regions in Canada. Urban development can negatively impact the Rusty-patched Bumble Bee by decreasing available forage and nesting resources (Glaum *et al*. 2017) and potentially by reducing gene flow (Jha 2015). The negative impacts of urbanization can be ameliorated somewhat through increasing available habitat in urban areas by creating semi-natural habitat and gardens with preferred flowers and permeable surfaces (for underground nesting and overwintering habitat) (Blackmore and Goulson 2014).

Threat 1.2: Commercial and industrial areas (high to medium impact)

This threat was not listed in the Rusty-patched Bumble Bee recovery strategy (ECCC 2020). Commercial and industrial areas will have many of the same impacts on the species as those listed under Threat 1.1. An increase in the area of impermeable surfaces decreases the availability of foraging, nesting, and overwintering resources. However, these effects can be mitigated through planting gardens and incorporating areas of pollinator habitat. Gardens and suitable pollinator habitat are uncommon within commercial and industrial areas, which makes this threat index higher than the index for housing and urban development.

<u>Threat 4: Transportation and service corridors (low to medium impact)</u>

Threat 4.1: Roads and railways (medium to low impact)

The potential negative impacts of roads on invertebrates are extensively reviewed in the recovery strategy (ECCC 2020). Briefly, roads can increase invertebrate mortality if there are collisions between individuals and vehicles (e.g., estimates of >133 million Hymenoptera killed each summer in southern Ontario; Baxter-Gilbert *et al.* 2015). However, recent work suggests that bumble bees and larger insects in general may be less impacted by vehicle collisions than previously thought (Fitch and Vaidya 2021; Schoenfeldt and Whitney 2022). Larger bees may be better at avoiding vehicles due to their tendency to fly higher than smaller insects, and they would be less impacted by air movements as vehicles pass by (Fitch and Vaidya 2021). Larger bees are more resilient to the negative impacts of roads (see Cameron and Sadd 2020 for a review), suggesting that the threat index for roads and railways is likely lower than stated in the recovery strategy (see ECCC 2020).

<u>Threat 7: Natural system modifications (low impact)</u>

Threat 7.1: Fire and fire suppression (low impact)

Fire may have a short-term negative impact on bumble bees by destroying nest sites and removing forage. However, fire as a tool for restoration may lead to positive effects on bumble bees by decreasing non-native species and promoting the establishment of native plant species, particularly in oak savannah habitat in Pinery Provincial Park.

Threat 5: Biological resource use (low impact)

Threat 5.3: Logging and wood harvesting (low impact)

This threat was not included in the threats table in the recovery strategy (ECCC 2020). Harvesting trees can deplete the woodland cover and decrease available nesting and overwintering sites (Liczner and Colla 2019). In addition, logging roads could also potentially destroy active nests and degrade potential nesting and overwintering sites. Decaying logs may be an important resource for nesting and overwintering bumble bees (Liczner and Colla 2019). Removing trees has the potential to remove important early spring forage for spring queens (Mola *et al*. 2021b).

Limiting Factors

The Rusty-patched Bumble Bee is at the northern limit of its range in Canada (Williams *et al.* 2014) and may be experiencing physiological or ecological constraints, which may be exacerbated by climate change (Kerr *et al.* 2015; Soroye *et al*. 2020). Relative to other bumble bees, the Rusty-patched Bumble Bee has a long colony cycle, being one of the first bees to emerge in the spring and one of the last to hibernate in the fall (MacFarlane 1974). This means a long season with a sufficient supply of food sources and lack of severe predation or disease within the colony are needed before the next generation is produced (i.e., the queen must be alive, and the colony must be healthy and strong in the fall to produce reproductives). This may make the species more vulnerable compared to other bees with shorter life cycles. The species is also likely experiencing genetic drift and inbreeding, as small subpopulations often have low levels of genetic diversity, which may make it more vulnerable to pathogens or other stressors (Darvill *et al*. 2006). Inbreeding depression could lead to the production of diploid males, which further reduces the effective subpopulation size (Zayed and Packer 2005). Local extirpations are possible and may have occurred at Pinery Provincial Park and St. Williams Conservation Reserve.

Number of Locations

Based on the primary threat of pathogen spillover and the extent of decline throughout this species' range, there is one location, specifically in southwestern Ontario. If there are other undiscovered sites, there could be another one or two locations. Also, it is possible there are no Rusty-patched Bumble Bees in Canada. Therefore, to be conservative, the number of locations is considered to be 0 to 3. Areas outside of southwestern Ontario are considered historical locations. While the last known Canadian sites (Pinery Provincial Park and St. Williams Conservation Area) are protected areas, they are surrounded, at least in part, by agricultural lands where managed bees are used. Additionally, they are subject to other threats such as climate change, agricultural inputs, and runoff. The extent and speed of pathogen dispersal is unknown but likely significant given the Rusty-patched Bumble Bee's rapid collapse throughout its large range (Cameron *et al.* 2011; Goulson pers. comm 2016 in USFWS 2016).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

This species is legally protected in Canada (on federal lands) under the *Species at Risk Act*, under which it was listed as Endangered on Schedule 1 in 2012 (Government of Canada 2012). Critical habitat was identified in the recovery strategy "as any suitable habitat located within a 1,000 m radius of any valid sightings of the species since 2005" (ECCC 2020). The species was listed as Endangered in Ontario in 2010 under the Ontario *Endangered Species Act* (Government of Ontario 2010). In Quebec, it is included on the *Liste des espèces susceptibles d'être désignées menacées ou vulnérables* (list of wildlife species likely to be designated threatened or vulnerable)(Québec Official Publisher 2020), which is produced pursuant to the *Loi sur les espèces menacées ou vulnérables* (RLRQ, c E-12.01) (LEMV) (Act respecting threatened or vulnerable species) (CQLR, c E-12.01) (Québec Official Publisher 2021).

In the United States, it was listed as Endangered in 2017 under the United States' *Endangered Species Act* (USFWS 2017). However, critical habitat has not yet been identified.

Non-Legal Status and Ranks

The Rusty-patched Bumble Bee is assessed on the IUCN Red List of Threatened Species (IUCNRedList.org) as Critically Endangered (Hatfield *et al.* 2015). The NatureServe Conservation Status Rankings (NatureServe 2020), with Centre de données sur le patrimoine naturel du Québec (2022), are as follows:

- Global: G2- Imperilled,
- Canada: N1- Critically Imperilled
- Provinces: New Brunswick SH; Ontario S1; Quebec S1
- United States: NNR - Unranked
- States: Connecticut SH; District of Columbia SNR; Georgia SH; Illinois S1; Indiana S1; Iowa SH; Kentucky SH; Maine SH; Maryland SH; Massachusetts SH; Michigan SH; Minnesota SNR; New Hampshire SH; New Jersey SNR; New York SH; North Carolina S1; North Dakota SH; Ohio S1; Pennsylvania S1; Rhode Island SNR; South Carolina SH; South Dakota SNR; Tennessee S1; Vermont SH; Virginia S1; West Virginia S1; Wisconsin S1

Note: The Rusty-patched Bumble Bee has not yet been assessed in New Brunswick (Queen's Printer for New Brunswick, 2013).

Habitat Protection and Ownership

Since 2000, the Rusty-patched Bumble Bee has only been recorded in Canada from Pinery Provincial Park (last observation in 2009) and the St. Williams Conservation Reserve (last observation in 2000). Both sites are overseen by Ontario Parks and a permit is required to collect insects (Queens Printer for Ontario 2021). At Pinery Provincial Park, park managers consider this species when planning land management (MacKenzie pers. comm. 2013 to 2021). Aside from the restrictions imposed by some landowners, no permits are required to collect bumble bees in general across Ontario, Quebec, and New Brunswick. However, the Ontario *Endangered Species Act* states that “No person shall kill, harm, harass, capture or take a living member of a species that is listed on the Species at Risk in Ontario List as an extirpated, endangered or threatened species.” If the Rusty-patched Bumble Bee is seen, it should not be harmed (Queen’s Printer for Ontario, 2020). A similar legislative requirement applies in Quebec (Québec Official Publisher 2021) and New Brunswick (Queen’s Printer for New Brunswick 2012). However, the Rusty-patched Bumble Bee is not yet legally designated as an at-risk species in New Brunswick (Queen’s Printer for New Brunswick 2013), and it is on the “Wildlife species which are likely to be designated as threatened or vulnerable” list for Quebec (Québec Official Publisher 2020).

ACKNOWLEDGEMENTS

The report writers would like to thank the many insect collectors, taxonomists, and collections who have helped build the Bumble Bees of North America Database, an initiative led by Dr. Leif Richardson. They would also like to thank all contributors to BumbleBeeWatch.org and iNaturalist.org for photos submitted, and all those who shared our #RustyPatchedGo on social media channels and participated in the search this summer. Thanks are also extended to John Ascher, Elaine Evans, John Klymko, Zach Portman, and Douglas Yanega for their assistance with ecology and database cleaning; Elaine Evans and Leif Richardson for identification assistance; Andrew Young, Étienne Normandin, and Peter T. Oboyski for providing photographs of specimens; and Amy Hall and Alistair MacKenzie for assistance and information related to Pinery Provincial Park. Lastly, they thank Wildlife Preservation Canada for providing information on survey efforts over the past decade, and thank the Xerces Society for Invertebrate Conservation and other Bumble Bee Watch partners for supporting such a valuable program.

Members of the Arthropods SSC—Myrle Ballard, Robert Buchkowski, Syd Cannings, Al Harris, Colin Jones, Jennifer Heron, John Klymko, Jessica Linton, Jayme Lewthwaite, Jeff Ogden, Leah Ramsay, John Richardson, Michel St. Germain, Sarah Semmler, Brian Starzomski, and Jeremy deWaard—provided review comments and ideas for assessment. Constructive comments on drafts were also contributed by Marie Archambault, Mary Sabine, Gina Schalk, Elisabeth Shapiro, Jennifer Thompson, and Alana Pindar. David McCorquodale (Arthropods Co-Chair), Rosie Soares, and Joanna James (COSEWIC Secretariat) provided support throughout the process.

Cover photo by Zach Portman.

AUTHORITIES CONTACTED

In addition to entomologists and curators associated with formal collections (see Collections Examined below), we also contacted other individuals who may have had relevant information for the report.

Allen, Sydney. Scientific and GIS Project Officer, COSEWIC Secretariat, Ottawa, Ontario.

Anderson, Robert. Canadian Museum of Nature, The Natural Heritage Campus, 1740 Pink Road, Gatineau, Quebec.

Ascher, John. Taxonomist and former curator at the American Museum of Natural History, currently at the National University of Singapore, Singapore.

Desrosiers, Nathalie. Biologist M.Sc., Service de la conservation de la biodiversité et des milieux humides, Direction de l'expertise sur la faune terrestre, l'herpétofaune et l'avifaune, Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs, Québec.

Evans, Elaine. Assistant Extension Professor, University of Minnesota, St. Paul, Minnesota.

Faulkner Jackson, Sheri. Head, Conservation Planning, Canadian Wildlife Service – Atlantic Region, Environment and Climate Change Canada, Sackville, NB.

Gardiner, Laura. A/ Ecosystem Scientist, Parks Canada, Abernethy Saskatchewan.

Gauthier, Isabelle. Biologist M.Sc., Coordonnatrice provinciale des espèces fauniques menacées et vulnérables, Direction générale de la gestion de la faune et des habitats, Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs, Québec.

Giguère, Sylvain. Biologist – Conservation Planning, Canadian Wildlife Service – Quebec Region, Environment and Climate Change Canada, Quebec City, Quebec.

Jones, Colin. Natural Heritage Information Centre Ontario, Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry, Peterborough, Ontario.

Klymko, John. Zoologist, Atlantic Canada Conservation Data Centre, Sackville, New Brunswick.

Picard, Karine. Head – Conservation Planning Unit, Canadian Wildlife Service – Quebec Region, Environment and Climate Change Canada, Quebec City, Quebec.

Pickett, Karolyne, Species at Risk Biologist, Conservation Planning Unit, Canadian Wildlife Service, Ontario Region, Environment and Climate Change Canada, Toronto, Ontario.

Richardson, Leif, Manager of the Bumblebees of North America Database (https://www.leifrichardson.org/bumble-bees-of-north-america.html), Gund Institute for Environment, University of Vermont, Burlington, Vermont.

Rowe, Genevieve, Lead Biologist, Native Pollinator Initiative, Wildlife Preservation Canada, Guelph, Ontario.

Sabine, Mary. Biologist, Species at Risk Program, Fish and Wildlife Branch, Department of Natural Resources, Hugh John Flemming Forestry Centre, Fredericton, New Brunswick.

Shepherd, Pippa. Species Conservation and Management Ecosystem Scientist III, Parks Canada, Vancouver, British Columbia.(*no response*)

Sweeney, Jon. Research Scientist, Atlantic Forestry Centre, Fredericton, New Brunswick.

Taylor, Tanya. Natural Heritage Information Centre Ontario, Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry, Peterborough, Ontario.

Williams, Paul. Natural History Museum, London, UK and BBSG Target Lead, IUCN SSC Bumblebee Subgroup.

Wu, Jenny. Scientific Project Officer, COSEWIC Secretariat, Canadian Wildlife Service, Environment and Climate Change Canada, Gatineau, Quebec.

INFORMATION SOURCES

Alford, D.V., 1975. Bumblebees. Davis-Poynter. xii + 352 pp., London.

Bartomeus, I., J.S. Ascher, J. Gibbs, B.N. Danforth, D.L. Wagner, S.M. Hedtke, and R. Winfree. 2013. Historical changes in northeastern US bee pollinators related to shared ecological traits. Proceedings of the National Academy of Sciences of the United States of America 110:4656-4660.

Baxter-Gilbert, J.H., J.L. Riley, C.J. Neufeld, J.D. Litzgus, and D. Lesbarrères. 2015. Road mortality potentially responsible for billions of pollinating insect deaths annually. Journal of Insect Conservation 19:1029-1035.

Benton, T. 2006. Bumblebees: the natural history & identification of the species found in Britain. Vol. 98. Harper, United Kingdom.

Biella, P., G. Bogliani, M. Cornalba, A. Manino, J. Neumayer, M. Porporato, P. Rasmont, and P. Milanesi. 2017. Distribution patterns of the cold adapted bumblebee *Bombus alpinus* in the Alps and hints of an uphill shift (Insecta: Hymenoptera: Apidae). Journal of Insect Conservation 21:357-366.

Blackmore, L.M., and D. Goulson. 2014. Evaluating the effectiveness of wildflower seed mixes for boosting floral diversity and bumblebee and hoverfly abundance in urban areas. Insect Conservation and Diversity 7:480-484.

BOLD, 2022. Bar Code of Life Data System v4. Website: http://www.boldsystems.org/ [accessed 19 December 2022].

Botías, C., J.C.J ones, T. Pamminger, I. Bartomeus, W.O. Hughes, and D. Goulson. 2021. Multiple stressors interact to impair the performance of bumblebee *Bombus terrestris* colonies. Journal of Animal Ecology 90:415-431.

Boulanger, L.W., G.W. Wood, E.A. Osgood, and C.O. Dirks. 1967. Native bees associated with the low-bush blueberry in Maine and Eastern Canada. Maine Agricultural Experiment Station Technical Bulletin 26.

Brinker, S.R., M. Garvey and C.D. Jones. 2018. Climate change vulnerability assessment of species in the Ontario Great Lakes Basin. Ontario Ministry of Natural Resources and Forestry, Science and Research Branch, Peterborough, ON. Climate Change Research Report CCRR-48. 85 p. + append. Website: https://www.natureserve.org/sites/default/files/ccrr-48_1.pdf.

Brooks, D.R., and J.J. Nocera. 2020. Bumble bee (*Bombus* spp.) diversity differs between forested wetlands and clearcuts in the Acadian forest. Canadian Journal of Forest Research. 50:1399-1404. https://cdnsciencepub.com/doi/10.1139/cjfr-2020-0094

Bush, E., and D.S. Lemmen (eds.). 2019. Canada's Changing Climate Report. Environment and Climate Change Canada. Government of Canada, Ottawa, ON. 444 pp.

Cameron, S.A., and B.M. Sadd. 2020. Global trends in bumble bee health. Annual Review of Entomology 65:209-232.

Cameron, S.A., J.D. Lozier, J.P. Strange, J.B. Koch, N. Cordes, L.F. Solter, and T.L. Griswold. 2011. Patterns of widespread decline in North American bumble bees. Proceedings of the National Academy of Sciences of the United States of America 108:662-667.

Cameron, S.A., H.M. Hines, and P.H. Williams. 2007. A comprehensive phylogeny of the bumble bees (*Bombus*). Biological Journal of the Linnean Society 91:161-188.

Carvell, C., A.F.G. Bourke, S. Dreier, S.N. Freeman, S. Hulmes, W.C. Jordan, J.W. Redhead, S. Sumner, J. Wang, and M.S. Heard. 2017. Bumblebee family lineage survival is enhanced in high-quality landscapes. Nature 543:547-549. doi.org/10.1038/nature21709

Carvell, C., A.F.G. Bourke, J.L. Osborne, and M.S. Heard. 2015. Effects of an agri-environment scheme on bumblebee reproduction at local and landscape scales. Basic and Applied Ecology 16:519-530.

Centre de données sur le patrimoine naturel du Québec. November 2022. Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MFFP), Quebec.

Chapman, R.E., J. Wang, and A.F.G. Bourke. 2003. Genetic analysis of spatial foraging patterns and resource sharing in bumble bee pollinators. Molecular Ecology 12:2801-2808.

Colla, S., and S. Dumesh. 2010. The bumble bees of Southern Ontario: Notes on natural history and distribution. Journal of the Entomological Society of Ontario 141:39–68.

Colla, S., and V. MacPhail. 2014. Conserving the Buzz – Saving Ontario Pollinators and Insect-Pollinated Plants from Extinction. Report Prepared by Wildlife Preservation Canada for Ontario Parks, Parks Canada, and the Ontario Ministry of Natural Resources and Forestry. December 2014.

Colla, S.R., and J.S. MacIvor. 2017. Questioning public perception, conservation policy, and recovery actions for honeybees in North America. Conservation Biology 31:1202-1204.

Colla, S.R., M.C. Otterstatter, R.J. Gegear, and J.D. Thomson. 2006. Plight of the bumble bee: Pathogen spillover from commercial to wild populations. Biological Conservation 129:461-467.

Colla, S.R., F. Gadallah, L. Richardson, D. Wagner, and L. Gall. 2012. Assessing declines of North American bumble bees (*Bombus* spp.) using museum specimens. Biodiversity and Conservation 21:3585-3595.

Colla, S.R., and L. Packer. 2008. Evidence for decline in eastern North American bumblebees (Hymenoptera: Apidae), with special focus on *Bombus affinis* Cresson. Biodiversity and Conservation 17:1379-1391.

Commission for Environmental Cooperation. 1997. Ecological regions of North America: toward a common perspective. Commission for Environmental Cooperation, Montreal, Quebec, Canada. 71 p. Map (scale 1:12,500,000). Revised 2006.

COSEWIC. 2010. COSEWIC assessment and status report on the Rusty-patched Bumble Bee *Bombus affinis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 34 pp.

COSEWIC. 2014. COSEWIC assessment and status report on the Gypsy Cuckoo Bumble Bee *Bombus bohemicus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 56 pp.

COSEWIC. 2018. COSEWIC guidelines for recognizing designatable units. Committee on the Status of Endangered Wildlife in Canada. https://cosewic.ca/index.php/en-ca/reports/preparing-status-reports/guidelines-recognizing-designatable-units.html [Accessed September 2021].

COSEWIC. 2019. COSEWIC assessment and status report on the Suckley's Cuckoo Bumble Bee *Bombus suckleyi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 70 pp.

Darvill, B., J.S. Ellis, G.C. Lye, G.C. and D. Goulson. 2006. Population structure and inbreeding in a rare and declining bumblebee, *Bombus muscorum* (Hymenoptera: Apidae). Molecular Ecology, 15:601-611.

Dawson, E.H., and L. Chittka. 2014. Bumblebees (*Bombus terrestris*) use social information as an indicator of safety in dangerous environments. Proceedings of the Royal Society B: Biological Sciences, 281(1785), p.20133174.

Dolan, C., S.R. Griffin, B. Bruninga-Socolar, and J.P. Klostermann. 2020. Flower and habitat preferences of the critically endangered rusty patched bumble bee (*Bombus affinis*) on a 4,000 acre tallgrass prairie preserve. Entomological Society of America Conference. Virtual Conference.

Dramstad, W.E. 1996. Do bumblebees (Hymenoptera: Apidae) really forage close to their nests? Journal of Insect Behavior 9:163-182.

Drapeau Picard, A-P. 2020a. Campagne d'inventaire 2019 visant à détecter le Bourdon à tache rousse (*Bombus affinis*) en Abitibi-Ouest. For Environment and Climate Change Canada. January 2020.

Drapeau Picard, A-P. 2020b. Campagne d'inventaire 2019 visant à détecter la présence de trois espèces de bourdons en péril en Abitibi-Ouest. For Environment and Climate Change Canada. February 2020.

Easterling, D.R., G.A. Meehl, C. Parmesan, S.A. Changnon, T.R. Karl, and L.O. Mearns. 2000. Climate extremes: observations, modeling, and impacts. Science 289:2068-2074.

Environment and Climate Change Canada (ECCC). 2020. Recovery Strategy for the Rusty-patched Bumble Bee (*Bombus affinis*) in Canada. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa. ix + 57 pp.

ESTR Secretariat. 2016. Mixedwood Plains Ecozone+ evidence for key findings summary. Canadian biodiversity: ecosystem status and trends 2010, Evidence for Key Findings Summary Report No. 7., Ottawa, Ontario: Canadian Councils of Resource Ministers.

Evans, E., pers. comm. 2020. *Email correspondence to V. MacPhail and S. Colla.* Various dates in 2020 and 2021. University of Minnesota.

Fijen, T.P. 2021. Mass-migrating bumblebees: An overlooked phenomenon with potential far-reaching implications for bumblebee conservation. Journal of Applied Ecology 58:274-280.

Fisher, R.M. 1984. Evolution and host specificity: a study of the invasion success of a specialized bumblebee social parasite. Canadian Journal of Zoology. 62:1641-1644.

Fitch, G., and C. Vaidya. 2021. Roads pose a significant barrier to bee movement, mediated by road size, traffic and bee identity. Journal of Applied Ecology 58:1177-1186.

Geib, J.C., J.P. Strange, and C. Galen. 2015. Bumble bee nest abundance, foraging distance, and host-plant reproduction: implications for management and conservation. Ecological Applications 25:768-778.

Glaum, P., M.-C. Simao, C. Vaidya, G. Fitch, and B. Iulinao. 2017. Big city *Bombus*: using natural history and land-use history to find significant environmental drivers in bumble-bee declines in urban development. Royal Society Open Science 4(5):170156. doi.org/10.1098/rsos.170156

Gibson, S.D., A.R. Liczner, and S.R. Colla. 2019. Conservation conundrum: At-risk Bumble bees (*Bombus* spp.) show preference for invasive tufted vetch (*Vicia cracca*) while foraging in protected areas. Journal of Insect Science 19:1-10.

Goka, K., K. Okabe, S. Niwa, and M. Yoneda. 2000. Parasitic mite infestation in introduced colonies of European bumble bees, *Bombus terrestris*. Japanese Journal of Applied Entomology and Zoology 44:47-50.

Goka K., K. Okabe, and M. Yoneda. 2006. Worldwide migration of parasitic mites as a result of bumblebee commercialization. Population Ecology 48:285-291.

Goulson, D. 2003. Bumblebees: their behaviour and ecology. Oxford University Press, Oxford, United Kingdom.

Goulson, D., G.C. Lye, and B. Darvill. 2008. Decline and conservation of bumble bees. Annual Review of Entomology 53:191-208.

Government of Canada. 2012. Species Profile - Rusty-patched Bumble Bee. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/rs_rusty_patched_bumble_bee_e_proposed.pdf. [accessed September 29, 2021]

Government of Ontario. 2010. Rusty-patched bumble bee. Scientific name: *Bombus affinis*. https://www.ontario.ca/page/rusty-patched-bumble-bee. [accessed September 29, 2021]

Graystock, P., D. Goulson, and W.O. Hughes. 2015. Parasites in bloom: flowers aid dispersal and transmission of pollinator parasites within and between bee species. Proceedings of the Royal Society B: Biological Sciences, 282(1813): 20151371. https://royalsocietypublishing.org/doi/10.1098/rspb.2015.1371

Graystock, P., E.J. Blane, Q.S. McFrederick, D. Goulson, and W.O. Hughes. 2016. Do managed bees drive parasite spread and emergence in wild bees? International Journal for Parasitology: Parasites and Wildlife 5:64-75.

Grixti, J.C., L.T. Wong, S.A. Cameron, and C. Favret. 2009. Decline of bumble bees (*Bombus*) in the North American Midwest. Biological Conservation 142:75-84.

Hatfield, R., S. Jepsen, R. Thorp, L. Richardson, S. Colla, S. Foltz Jordan, and E. Evans. 2015. *Bombus affinis*. The IUCN Red List of Threatened Species 2015: e.T44937399A46440196. https://www.iucnredlist.org/species/44937399/46440196. [accessed September 2020].

Health Canada. 2020. Update on the Neonicotinoid Pesticides. Health Canada's Pest Management Regulatory Agency. https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/update-neonicotinoid-pesticides-2020.html [accessed June 30, 2022].

Health Canada. 2021. Re-evaluation Decision RVD2021-05, Imidacloprid and Its Associated End-use Products. Health Canada's Pest Management Regulatory Agency. https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/reevaluation-decision/2021/imidacloprid.html [accessed June 30, 2022].

Heinrich, B., 2004. Bumblebee economics. Harvard University Press, Cambridge, Massachusetts. 246 pp. + 2 pl.

Hogg, A., and C.D. Jones. 2018. A landscape-scale assessment of pollinator habitat in southern Ontario. Ontario Ministry of Natural Resources and Forestry, Science and Research Branch, Peterborough, ON. Science and Research Technical Report TR-22. 29 pp.

IUCN-CMP. 2006. Unified classification of conservation actions. Page 12 in IUCN and Conservation Measures Partnership.

Jepsen, S., E. Evans, R. Thorp, R. Hatfield, and S.H. Black. 2013. Petition to list the Rusty-patched Bumble Bee *Bombus affinis* (Cresson), 1863, as an Endangered species under the U.S. Endangered Species Act. The Xerces Society for Invertebrate Conservation, Portland, Oregon. 42 pp.

Jha, S. 2015. Contemporary human-altered landscapes and oceanic barriers reduce bumble bee gene flow. Molecular Ecology 24:993-1006.

Kallioniemi, E., J. Åström, G.M. Rusch, S. Dahle, S. Åström, and O.J. Gjershaug. 2017. Local resources, linear elements and mass-flowering crops determine bumblebee occurrences in moderately intensified farmlands. Agriculture, Ecosystems & Environment 239:90-100.

Kenna, D., H. Cooley, I. Pretelli, A.R. Rodrigues, S.D. Gill, and R.J. Gill. 2019. Pesticide exposure affects flight dynamics and reduces flight endurance in bumblebees. Ecology and Evolution 9:5637-5650.

Kerr, J.T., A. Pindar, P. Galpern, L. Packer, S.G. Potts, S.M. Roberts, P. Rasmont, O. Schweiger, S.R. Colla, L.L. Richardson, D.L. Wagner, L.F. Gall, D.S. Sikes, and A. Pantoja. 2015. Climate change impacts on bumblebees converge across continents. Science 349(6244):177-180. doi:10.1126/science.aaa7031

Kozak, P., pers. comm. 2019. *Email correspondence to S.R. Colla* January. 2019. Provincial Apiarist, Ontario Ministry of Agriculture, Food, and Rural Affairs, Guelph, Ontario.

Kissinger, C.N., S.A. Cameron, R.W. Thorp, B. White, and L.F. Solter. 2011. Survey of bumble bee (*Bombus*) pathogens and parasites in Illinois and selected areas of northern California and southern Oregon. Journal of Invertebrate Pathology 107:220-224.

Klymko, J., and D. Sabine. 2015. Verification of the occurrence of *Bombus affinis* (Hymenoptera: Apidae) in New Brunswick, Canada. Journal of the Acadian Entomological Society 11:22-25.

Knight, M.E., A.P. Martin, S. Bishop, J.L. Osborne, R.J. Hale, A. Sanderson, and D. Goulson. 2005. An interspecific comparison of foraging range and nest density of four bumblebee (*Bombus*) species. Molecular Ecology 14:1811-1820.

Kraus, F.B., S. Wolf, and R.F.A. Moritz, 2009. Male flight distance and population substructure in the bumblebee *Bombus terrestris*. Journal of Animal Ecology 78:247-252.

Laverty, T.M., and L.D. Harder. 1988. The bumble bees of eastern Canada. The Canadian Entomologist 120:965-987.

Liczner, A.R., V.P. MacPhail, D.A. Woollett, N.L. Richards, and S.R. Colla. 2021. Training and usage of detection dogs to better understand bumble bee nesting habitat: Challenges and opportunities. PLoS ONE 16(5): e0249248. doi.org/10.1371/journal.pone.0249248

Liczner, A.R., and S.R. Colla. 2019. A systematic review of the nesting and overwintering habitat of bumble bees globally. Journal of Insect Conservation 23:787-801.

MacKenzie, A., pers. comm. 2013–2021. *Various email correspondence and in person conversations with S.R. Colla*, 2013-2021. Resource Management & Discovery Supervisor, Pinery Provincial Park, Ontario.

MacFarlane, R.P. 1974. Ecology of *Bombinae,* (Hymenoptera: Apidae) of Southern Ontario, with emphasis on their natural enemies and relationships with flowers. Ph.D. dissertation, University of Guelph, Guelph, Ontario, Canada. 210 pp.

MacPhail, V.J. 2021. Assessing the benefits, challenges, and scientific value of community science programs: a case study using Bumble Bee Watch. Ph.D. Thesis, York University.

MacPhail, V.J., S.D. Gibson, and S.R. Colla. 2020a. Community science participants gain environmental awareness and contribute high quality data but improvements are needed: insights from Bumble Bee Watch. PeerJ 8:e9141 doi.org/10.7717/peerj.9141

MacPhail, V.J., S.D. Gibson, R. Hatfield and S.R. Colla. 2020b. Using Bumble Bee Watch to investigate the accuracy and perception of bumble bee (*Bombus* spp.) identification by community scientists. PeerJ 8:e9412 doi.org/10.7717/peerj.9412

MacPhail, V.J., L.L. Richardson, and S.R. Colla. 2019. Incorporating citizen science, museum specimens, and field work into the assessment of extinction risk of the American Bumble Bee (*Bombus pensylvanicus* De Geer 1773) in Canada. Journal of Insect Conservation 23:597-611.

McFarland, K., L. Richardson, and S. Zahendra. 2015. Rusty-patched Bumble Bee (*Bombus affinis*): Report to the Vermont Endangered Species Committee. 10.13140/RG.2.1.1305.9289.

Mitchell, T.B. 1962. Bees of the Eastern United States Vol 2. North Carolina Agricultural Experiment Station Technical Publication 152, 557 pp.

Moffat, C., S.T. Buckland, A.J. Samson, R. McArthur, V. Chamosa Pino, K.A. Bollan, J.T.J. Huang, and C.N. Connolly. 2016. Neonicotinoids target distinct nicotinic acetylcholine receptors and neurons, leading to differential risks to bumblebees. Scientific Reports 6, 24764 (2016). https://doi.org/10.1038/srep24764

Mola, J.M., L.L. Richardson, G. Spyreas, D.N. Zaya, and I.S. Pearse. 2021a. Long-term surveys support declines in early season forest plants used by bumblebees. Journal of Applied Ecology 58:1431-1441.

Mola, J.M., J. Hemberger, J. Kochanski, L.L. Richardson, and I.S. Pearse. 2021b. The importance of forests in bumble bee biology and conservation. BioScience 71(12): 1234-1248. doi.org/10.1093/biosci/biab121

NatureServe. 2020. NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. Available https://explorer.natureserve.org/. [accessed September 1, 2020].

New Brunswick (NB) Department of Natural Resources and Energy Development. 2021. Bohemian Cuckoo Bumble Bee *Bombus bohemicus* in New Brunswick: Status Report. Prepared for the Committee on the Status of Species at Risk in New Brunswick (NB COSSAR). Available: https://www1.gnb.ca/0078/SpeciesAtRisk/details-e.asp?ID=91 [Accessed February 9, 2022].

Niwa, S., H. Iwano, S.I. Asada, M. Matsumura, and K. Goka. 2004. A microsporidian pathogen isolated from a colony of the European bumblebee, *Bombus terrestris*, and infectivity on Japanese bumblebee. Japanese Journal of Applied Entomology and Zoology 48:60-64.

Normandin, E., pers. comm. 2020. *Email correspondence to V. MacPhail.* December 2020. Coordonnateur des collections zoologiques, Ouellet-Robert entomological collection, Université de Montréal. Montreal, Quebec.

Oboyski, P., pers. comm. 2020. *Email correspondence to V. MacPhail.* December 2020. Executive Director, Essig Museum of Entomology, University of California, Berkeley, California.

O'Connor, S., K.J. Park, and D. Goulson. 2012. Humans versus dogs; a comparison of methods for the detection of bumble bee nests. Journal of Apicultural Research 51:204-211.

Ogilvie, J.E., S.R. Griffin, Z.J. Gezon, B.D. Inouye, N. Underwood, D.W. Inouye, and R.E. Irwin. 2017. Interannual bumble bee abundance is driven by indirect climate effects on floral resource phenology. Ecology Letters 20:1507-1515.

Ontario Biodiversity Council, 2010. State of Ontario's biodiversity 2010–highlights report. A report of the Ontario Biodiversity Council, Peterborough, Ontario.

Ontario Biodiversity Council, 2011. Ontario's Biodiversity Strategy, 2011: Renewing Our Commitment to Protecting What Sustains Us, Peterborough, Ontario.

Osborne, J.L., S.J. Clark, R.J. Morris, I.H. Williams, J.R. Riley, A.D. Smith, D.R. Reynolds, and A.S. Edwards. 1999. A landscape-scale study of bumble bee foraging range and constancy, using harmonic radar. Journal of Applied Ecology 36:519-533.

Osborne, J.L., and I.H. Williams. 2001. Site constancy of bumble bees in an experimentally patchy habitat. Agriculture, Ecosystems and Environment. 83:129-141.

Otterstatter, M.C., T.L. Whidden, and R.E. Owen. 2002. Contrasting frequencies of parasitism and host mortality among phorid and conopid parasitoids of bumble-bees. Ecological Entomology 27:229-237.

Otterstatter, M.C., and J. D. Thomson. 2008. Does pathogen spillover from commercially reared bumble bees threaten wild pollinators? PloS ONE 3(7): e2771.

Pfeiffer, V., J. Silbernagel, C. Guédot, and J. Zalapa. 2019. Woodland and floral richness boost bumble bee density in cranberry resource pulse landscapes. Landscape Ecology 34:979-996.

Pindar A., E.K. Mullen, M.B. Tonge, E. Guzman-Novoa, and N.E. Raine. 2017. Status and Trends of Pollinator Health in Ontario. University of Guelph report prepared for Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 238 pp.

Plath, O.E. 1922. Notes on the nesting habits of several North American bumblebees. Psyche 29:189-202.

Plath, O.E. 1927. Notes on the hibernation of several North American bumblebees. Annals of the Entomological Society of America 20:181-192.

Plath, O.E. 1934. Bumblebees and Their Ways. The Macmillan Company, New York, New York. 201 pp.

Plischuk, S., S. Salvarrey, N. Arbulo, E. Santos, J.H. Skevington, S. Kelso, P.D. Revainera, M.D. Maggi, C. Invernizzi, and C.E. Lange. 2017. Pathogens, parasites, and parasitoids associated with bumble bees (*Bombus* spp.) from Uruguay. Apidologie 48:298-310.

Québec Official Publisher. 2020. E-12.01, r. 5 - Liste des espèces floristiques et fauniques susceptibles d'être désignées menacées ou vulnérables (List of plant and wildlife species which are likely to be designated as threatened or vulnerable). http://legisquebec.gouv.qc.ca/en/showdoc/cr/E-12.01,%20r.%205/20200212 [accessed September 29, 2021].

Québec Official Publisher. 2021. E-12.01 - *Loi sur les espèces menacées ou vulnérables* (Act respecting threatened or vulnerable species). http://legisquebec.gouv.qc.ca/en/showDoc/cs/E-12.01?&digest= [accessed September 29, 2021]

Queen's Printer for New Brunswick. 2012. *Species at Risk Act* (S.N.B. 2012, c.6). http://laws.gnb.ca/en/showfulldoc/cs/2012-c.6//20210929 [accessed September 29, 2021].

Queen's Printer for New Brunswick. 2013. List of Species at Risk Regulation - *Species at Risk Ac*t. New Brunswick. Regulation 2013-38 under *Species at Risk Act* (O.C. 2013-143). http://laws.gnb.ca/en/ShowTdm/cr/2013-38 [accessed September 29, 2021].

Queen's Printer for Ontario. 2020. *Endangered Species Act*, 2007, S.O. 2007, c. 6. https://www.ontario.ca/laws/statute/07e06 [accessed September 29, 2021].

Queen's Printer for Ontario. 2021. Research in provincial parks and conservation reserves. Website: https://www.ontarioparks.com/scienceresearch/research [accessed August 29, 2021].

Rao, S., and K.M. Skyrm. 2013. Nest density of the native bumble bee, *Bombus nevadensis* Cresson (Hymenoptera: Apoidea), in an agricultural landscape. Journal of the Kansas Entomological Society 86:93-97.

Richardson, L., pers. comm. 2020. *Email correspondence to V. MacPhail.* Various dates in 2020 and 2021. Manager of the Bumblebees of North America Database (https://www.leifrichardson.org/bumble-bees-of-north-america.html), Vermont.

Rondeau, S., and N.E. Raine. 2020. Quantifying exposure of bumblebee queens to pesticide residues when hibernating in agricultural soils. Entomological Society of America Annual Conference.

Rowe, L.M., D.L. Cuthrell, and H.D. Enander. 2019. Assessing bumble bee diversity, distribution, and status for the Michigan Wildlife Action Plan. Prepared by Michigan Natural Features Inventory (Michigan State University Extension) for Michigan Department of Natural Resources (Wildlife Division). MNFI Report No. 2019-33.

Ruiz-González, M.X., J. Bryden, Y. Moret, C. Reber-Funk, P. Schmid-Hempel, and M.J. Brown. 2012. Dynamic transmission, host quality, and population structure in a multihost parasite of bumblebees. Evolution 66:3053-3066.

Rust, R.W. 1979. Pollination of *Impatiens capensis*: pollinators and nectar robbers. Journal of the Kansas Entomological Society 52:297-308.

Saint-Germain, M. 2017. Campagne d'inventaire 2017 visant à détecter le Bourdon à tache rousse au Québec. Final report. Produced for Environment and Climate Change Canada. October 2017.

Saint-Germain, M. 2018. Campagne d'inventaire 2018 visant à détecter le Bourdon à tache rousse (*Bombus affinis* Cresson) au Québec. . Final report. Produced for Environment and Climate Change Canada. December 2018.

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.

Samuelson, E.E.W., Z.P. Chen-Wishart, R.J. Gill, and E. Leadbeater. 2016. Effect of acute pesticide exposure on bee spatial working memory using an analogue of the radial-arm maze. Scientific Reports 6:38957 doi.org/10.1038/srep38957

Schmid-Hempel, R., M. Eckhardt, D. Goulson, D. Heinzmann, C. Lange, S. Plischuk, L.R. Escudero, R. Salathé, J.J. Scriven, and P. Schmid-Hempel. 2014. The invasion of southern South America by imported bumblebees and associated parasites. Journal of Animal Ecology 83:823-837.

Schoenfeldt, A., and K.S. Whitney. 2022. Bumble bee (*Bombus* spp.) abundance in New York highway roadsides across levels of roadside mowing and road traffic. Northeastern Naturalist 29:55-72.

Simanonok, M.P., C.R. Otto, R.S Cornman, D.D Iwanowicz, J.P Strange, and T.A. Smith. 2020. A century of pollen foraging by the endangered rusty patched bumble bee (*Bombus affinis*): inferences from molecular sequencing of museum specimens. Biodiversity and Conservation 30:123-137. https://link.springer.com/article/10.1007/s10531-020-02081-8

Simon-Delso, N., V. Amaral-Rogers, L.P. Belzunces, J.M. Bonmatin, M. Chagnon, C. Downs, L. Furlan, D.W. Gibbons, C. Giorio, V. Girolami, and D. Goulson. 2015. Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites. Environmental Science and Pollution Research, 22:5-34.

Sirois-Delisle, C., and J.T. Kerr. 2018. Climate change-driven range losses among bumblebee species are poised to accelerate. Scientific Reports 8:1-10. doi.org/10.1038/s41598-018-32665-y

Soroye, P., T. Newbold, and J. Kerr. 2020. Climate change contributes to widespread declines among bumble bees across continents. Science 367:685-688.

Stanley, D.A., and N.E. Raine. 2016. Chronic exposure to a neonicotinoid pesticide alters the interactions between bumblebees and wild plants. Functional Ecology 30: 1132-1139.

Stanley, D.A., A.L. Russell, S.J. Morrison, C. Rogers, and N.E. Raine. 2016. Investigating the impacts of field-realistic exposure to a neonicotinoid pesticide on bumblebee foraging, homing ability and colony growth. Journal of Applied Ecology 53:1440-1449.

Statistics Canada. 2016. Table 051-0001 - Estimates of population, by age group and sex for July 1, Canada, provinces and territories, annual (persons unless otherwise noted), CANSIM (database). Available at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501 [accessed March 3, 2017].

Statistics Canada 2016. Table 32-10-0406-01 Land Use https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210040601

Stout, J.C., and D. Goulson. 2000. Bumble Bees in Tasmania: their distribution and potential impact on Australian flora and fauna. Bee World 81:80-86.

Strange, J.P., and A.D. Tipodi. 2019. Characterizing bumble bee (*Bombus*) communities in the United States and assessing a conservation monitoring method. Ecology and Evolution 9:1061-1069.

Stubbs, C.S., and F.A. Drummond. 2001. *Bombus impatiens* (Hymenoptera: Apidae): an alternative to *Apis mellifera* (Hymenoptera: Apidae) for lowbush blueberry pollination. Journal of Economic Entomology, 94:609-616.

Sugden, E.A. 1985. Pollinators of *Astragalus monoensis* Barneby (Fabaceae): New host records; potential impact of sheep grazing. Great Basin Naturalist 45:299-312.

Szabo, N.D., S.R. Colla, D.L. Wagner, L.F. Gall, and J.T. Kerr. 2012. Do pathogen spillover, pesticide use, or habitat loss explain recent North American bumblebee declines? Conservation Letters 5:232-239.

Thomson, D.M. 2004. Competitive interactions between the invasive European honey bee and native bumble bees. Ecology 85:458-470.

Thomson, D.M. 2016. Local bumble bee decline linked to recovery of honey bees, drought effects on floral resources. Ecology Letters 19:1247-1255.

Thomson, J.D., S.C. Peterson, and L.D. Harder. 1987. Response of traplining bumble bees to competition experiments: shifts in feeding location and efficiency. Oecologia 71:295-300.

Tokarev, Y. S., W.-F. Huang, L.F. Solter, J.M. Malysh, J.J. Becnel, and C.R. Vossbrinck. 2020. A formal redefinition of the genera *Nosema* and *Vairimorpha* (Microsporidia: Nosematidae) and reassignment of species based on molecular phylogenetics. Journal of Invertebrate Pathology 169:107279. doi.org/10.1016/j.jip.2019.107279

Tripodi, A.D., A.L. Szalanski, and J.P. Strange. 2018. Novel multiplex PCR reveals multiple trypanosomatid species infecting North American bumble bees (Hymenoptera: Apidae: *Bombus*). Journal of Invertebrate Pathology 153:147-155.

Tsvetkov, N., O. Samson-Robert, K. Sood, H.S. Patel, D.A. Malena, P.H. Gajiwala, P. Maciukiewicz, V. Fournier, and A. Zayed, A. 2017. Chronic exposure to neonicotinoids reduces honey bee health near corn crops. Science 356:1395-1397.

United States Fish and Wildlife Service (USFWS). 2016. Rusty Patched Bumble Bee (*Bombus affinis*) Species Status Assessment. Final Report, Version 1. June 2016.

United States Fish and Wildlife Service (USFWS). 2017. Endangered Species Status for Rusty Patched Bumble Bee. Federal Register 82:3186-3209.

United States Fish and Wildlife Service (USFWS). 2019. Draft Recovery Plan for the Rusty Patched Bumble Bee (*Bombus affinis*). Midwest Regional Office, Bloomington, MN.

United States Fish and Wildlife Service (USFWS). 2020. Rusty-patched Bumble Bee Ex-Situ assessment and planning workshop report [Online] http://cpsg.org/content/rusty-patched-bumble-bee-ex-situ-assessment-and-planning-workshop-report [Accessed December 20, 2020]

van Vierssen Trip, N., V.J. MacPhail, S.R. Colla, and B. Olivastri. 2020. Examining the public's awareness of bee (Hymenoptera: Apoidae: Anthophila) conservation in Canada. Conservation Science and Practice 2020;2:e293. https://doi.org/10.1111/csp2.293

Walther-Hellwig, K., G. Fokul, R. Frankl, R. Buchler, K. Ekschmitt, and V. Wolters. 2006. Increased density of honeybee colonies affects foraging bumblebees. Apidologie 37:517-532.

Walther-Hellwig, K., and R. Frankl. 2000a. Foraging distances of *Bombus muscorum, Bombus lapidariu*s, and *Bombus terrestris* (Hymenoptera, Apidae). Journal of Insect Behavior 13:239-246

Walther-Hellwig, K., and R. Frankl. 2000b. Foraging habitats and foraging distances of bumblebees, *Bombus* spp. (Hym., Apidae), in an agricultural landscape. Journal of Applied Entomology 124:299-306.

Waters, J., S. O'Connor, K.J. Park, and D. Goulson. 2011. Testing a detection dog to locate bumblebee colonies and estimate nest density. Apidologie 42:200-205.

Whittington, R., and M.L. Winston. 2003. Effects of *Nosema bombi* and its treatment fumagillin on bumble bee (*Bombus occidentalis*) colonies. Journal of Invertebrate Pathology 84:54-58.

Williams, P.H. 2021. Not just cryptic, but a barcode bush: PTP re-analysis of global data for the bumblebee subgenus *Bombus s. str*. supports additional species (Apidae, genus *Bombus*). Journal of Natural History. 55:271-282. https://www.tandfonline.com/doi/full/10.1080/00222933.2021.1900444

Williams, P.H., R.W. Thorp, L.L. Richardson, and S.R. Colla. 2014. Bumble Bees of North America: An Identification Guide. Princeton University Press, Princeton, New Jersey. 208 pp.

Yanega D., pers. comm. 2020. *Email correspondence to V. MacPhail.* December 2020. Department of Entomology, Entomology Research Museum, University of California, Riverside, California.

Young, A., pers. comm. 2020. *Email correspondence to V. MacPhail.* December 2020. Assistant Professor, Ontario Agricultural College, School of Environmental Sciences, University of Guelph, Guelph, Ontario.

Zars, T. 2000. Behavioral functions of the insect mushroom bodies. Current Opinion in Neurobiology 10:790-795.

Zayed, A., and L. Packer. 2005. Complementary sex determination substantially increases extinction proneness of haplodiploid populations. Proceedings of the National Academy of Sciences 102:10742-10746.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Dr. Sheila Colla is an Associate Professor in the Faculty of Environmental and Urban Change at York University and interdisciplinary Conservation Science Research Chair. She received her Hons B.Sc. in Zoology at the University of Toronto (St. George campus) in 2005 and PhD in Biology from York University in 2012. She held an NSERC Industrial Postdoctoral Fellowship with Wildlife Preservation Canada and the prestigious Liber Ero Postdoctoral Fellowship at the University of Toronto (St. George campus). Colla has published extensively on the ecology, threats and conservation of North American bumble bees, including *B. affinis*. She has been studying wild bumble bees for over 15 years and was the last person to find *B. affinis* in Canada (2005 & 2009, Pinery Provincial Park). Colla is the North American Coordinator for the IUCN SSC Bumblebee Specialist Group. She helped coordinate the IUCN Red List assessments for the 46 North American bumble bee species. Her research was the first quantitative evidence of the declines of bees in North America, and the first to document the decline of *B. affinis* in Canada. Colla has focused her research on bumble bees in southern Ontario for over a decade. She has served on the COSEWIC Arthropods Subcommittee, COSSARO as well as various society, journal and grant peer review committees. She is working closely with the USFWS and Xerces Society on conservation management planning for *B. affinis* in the USA. In addition, she is regularly sought after as a bumble bee conservation expert by government agencies, the public and academics.

Dr. Amanda Liczner received her Spec. Hons. B.Sc. in Biology at York University in 2014, M.Sc. in Biology from York University in 2016, PhD in Biology from York University in 2020, and is currently a postdoctoral fellow at the University of British Columbia Okanagan. Liczner's Ph.D. was focused on determining the habitat for at-risk bumble bee species across North America, including *B. affinis*. She is collaborating with international experts to identify priority areas for bumble bee conservation across Canada. She is also working to expand our limited knowledge on bumble bee nesting requirements using citizen science and detection dog data on bumble bee nest locations. Throughout her dissertation, Liczner has used GIS analyses, spatial data, and has accessed a long-term bumble bee occurrence database to address her research question.

Dr. Victoria MacPhail received her Hons B.Sc. in Biology at the University of Prince Edward Island in 2004, her M.Sc. in Environmental Biology from the University of Guelph in 2007, and her PhD in Environmental and Urban Change from York University in 2021. MacPhail is a pollination biologist who has been researching and working to conserve pollinators for over 18 years in academia, government, conservation authority, and environmental non-governmental organizations. She was the coordinator of the NSERC-Canadian Pollination Initiative during its formative period. She is also a founding member and current Co-chair of Pollination Guelph, a charitable organization dedicated to protecting pollinators and their habitat. MacPhail has been focusing her efforts on bumble bees since 2012, with activities ranging from leading field surveys across eastern Canada (including Ontario, Quebec, New Brunswick, and Prince Edward Island) to the development of the Bumble Bee Watch community science program and the development of a captive breeding program for at-risk bumble bee species. Her current research focusses on using community science and researcher data for the conservation of native bumble bees.

COLLECTIONS EXAMINED

Entomologists and curators of formal insect collections were contacted (see also **Authorities Contacted** above). Due to COVID-19, no collections were examined in person.

New Brunswick

New Brunswick Museum
277 Douglas Ave.
St John, NB E2K 2E5
Donald McAlpine

Ontario

Canadian National Collection of Insects, Arachnids and Nematodes
Agriculture and Agri-Food Canada,
K.W. Neatby Building, 960 Carling Ave.
Ottawa, ON, K1A 0C6
Sophie Cardinal

Dept of Biology, York University (BEES)
Lumbers Building RM 345
York University
4700 Keele Street
Toronto, ON M3J 1P3
Laurence Packer

Dept of Environmental Biology, University of Guelph
Guelph, ON N1G 2W1
Steve Paiero
Andrew Young

Royal Ontario Museum
100 Queen's Park
Toronto, ON M5S 2C6
Doug Currie
Brad Hubley

Quebec

Natural History Museum
Bishop's University
Lennoxville, QC J1M 1Z7
Jade Savage

Ouellet-Robert Collection
Université de Montréal Biodiversity Centre
4101 Sherbrooke East
Montreal, QC H1X 2B2
Colin Favret
Louise Cloutier

Department of Biology, Université Laval
Alexandre-Vachon Bldg
Quebec City, QC G1K 7P4
Conrad Cloutier

Lyman Entomological Museum
McGill University, Macdonald Campus
21,111 Lakeshore Road
Ste-Anne-de-Bellevue, QC H9X 3V9
Stephanie Boucher

Montréal Insectarium
4581 Sherbrooke St E
Montreal, Quebec H1X 2B2
Maxim Larrivée
Michel St. Germain

Other Jurisdictions:

American Museum of Natural History
Central Park West at 79th St.
New York, New York 10024-5192
Christine Lebeau
Christine Johnson
(Communications regarding a record databased by the AMNH)

William Patterson University
300 Pompton Rd, Wayne, New Jersey 07470, United States I
David Gilley, Associate Professor of Biology
Hadel Go, former student

Essig Museum of Entomology
1170 Valley Life Science Building
University of California, Berkeley, California
Peter T Oboyski, Executive Director

Dept. of Entomology, Entomology Research Museum
University of California, Riverside, California
Doug Yanega

USDA-ARS Pollinating Insect-Biology, Management, Systematics Research
Logan, Utah
Terry Griswold, Administrative contact
Harold Ikerd, Technical contact

Appendix 1. Previously reported occurrences or specimens of Rusty-patched Bumble Bee in Ontario, Quebec, and New Brunswick, Canada that were deemed likely erroneous and not included in the analyses of geographic range.

Ontario

The Rusty-patched Bumble Bee recovery strategy (ECCC 2020) included points in two regions in northern Ontario (near Kenora and near White River) that were not mentioned in the previous COSEWIC status report (2010) or in earlier publications such as Laverty and Harder (1988). Upon further investigation, these two sites and a third in southern Ontario are believed to be erroneous identifications.

1) There were initially three different sites near Kenora, Ontario in the data obtained for this report: one from the BBNA database and two from GBIF. All three appear to be referencing a single specimen:

   i) The BBNA record, BBNA_411545, had the Institution as Essig Museum of Entomology, University of California, Berkeley, CA (EMEC), the data source as Doug Yanega 03-07-2013, with the note “LLR 2019: edited coordinates”; the collector was JR Powers on August 7, 1981, and the site was 15 mi SE of Kenora, with no determiner listed.

   ii) The first GBIF record, #658644248, had the Institution as USDA-ARS, Collection as BBSL, Catalog Number JPS9556, recorded by J.R. Powers on August 7, 1981, identified by J.B. Koch 2009.

   iii) The second GBIF record, 2328391078, had the Institution as EMEC, Collection JPS, Catalog Number JPS9556, recorded by J.R. Powers on August 7, 1981, with no determiner listed.

The University of California Entomology database also confirms the original determiner and original collection information, including the locality information of “15 mi SE of Kenora” (Yanega pers. comm. 2020). Oboyski (pers. comm. 2020) provided photos of the specimen with EMEC Catalog Number JPS9556 and, after discussion with experts (Evans pers. comm. 2020; Richardson pers. comm. 2020), it was determined unlikely to be a Rusty-patched Bumble Bee, although there was not a consensus as to what it was.

2) The record near White River, Ontario (from BBNA database, BBNA_177841) was collected June 1, 1915 by FWL Sladen, and previously determined by Sheila Colla as Rusty-patched Bumble Bee. Photos were obtained of the specimen at the University of Guelph (Young pers. comm. 2020), and it was determined (Evans pers. comm. 2020, Richardson pers. comm. 2020) to be in subgenus *Pyrobombus*, likely the Half-black Bumble Bee, *Bombus vagans*.

3) The BBNA database (BBNA_915779) includes a record from southern Ontario, near Brantford, but based on additional label data, it was determined by Victoria MacPhail to be a typographical error, as it should have been in Lone Rock, Wisconsin, 28 September 1993.

Quebec

The Rusty-patched Bumble Bee recovery strategy (ECCC 2020) indicated that the historical range of the Rusty-patched Bumble Bee extended east to three areas in northern Quebec (near Canton Paradis, Macamic, and Trécesson/La Ferme region). These points were not in COSEWIC (2010) or earlier publications such as Laverty and Harder (1988). Upon further investigation, these and an additional point near La Tuque are believed to be erroneous identifications.

1) The three north-western Quebec points, which were stored in the Environment and Climate Change Canada – Quebec dataset (ECCC database), were for bees collected in 1942 (Macamic and Trécesson/La Ferme regions) and 1943 (Canton Paradis). Photos of the specimens were obtained (Normandin pers. comm. 2020). After review (by Victoria MacPhail, Sheila Colla and Leif Richardson) all three were also determined to be misidentifications, likely (although not 100% confident) the Red-belted Bumble Bee (*Bombus rufocinctus*) (Macamic, La Ferme) and Sanderson's Bumble Bee (*Bombus sandersoni*) (Canton Paradis).

2) The BBNA database (BBNA_892027) includes a record from near La Tuque in eastern Québec; it was determined by Victoria MacPhail to be a typographical error with the correct site being in Hartford, Connecticut, 11 August 1895.

New Brunswick

Two records of the Rusty-patched Bumble Bee purportedly from New Brunswick, Canada:

1) GBIF database (gbifid# 767116784; https://www.gbif.org/occurrence/767116784), apparently from New Brunswick on Sept 19, 1936, and housed at USDA-ARS BBSL (Bee Biology and Systematics Laboratory) (catalogue id# BOMBUS1615). Attempts to locate this specimen have not been successful. As this record has no coordinates, collector, determiner, or virtually any other data (GBIF notes "This record is published without coordinates, but it includes a textual description of its location"), it is likely an error.

2) Mitchell (1962) included New Brunswick as part of the range of the Rusty-patched Bumble Bee with no evidence. COSEWIC (2010) and Klymko and Sabine (2015) believed this to be an incorrect interpretation of a specimen at the Cornell University Insect Collection from New Brunswick, New Jersey. But see Klymko and Sabine (2015) for an explanation of why New Brunswick is part of the range based on other records.