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Management Plan for the Yellow-banded Bumble Bee (*Bombus terricola*) in Canada

Yellow-banded Bumble Bee

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For copies of the management plan, or for additional information on species at risk, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk (SAR) Public Registry[1].

Cover illustration: Female Yellow-banded Bumble Bee, New Brunswick. Photo by Denis Doucet, used with permission.

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[1] www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996)[2] agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada[3]. Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of management plans for listed species of special concern and are required to report on progress within five years after the publication of the final document on the SAR Public Registry.

The Minister of Environment and Climate Change and Minister responsible for the Parks Canada Agency is the competent minister under SARA for the Yellow-banded Bumble Bee and has prepared this management plan, as per section 65 of SARA. To the extent possible, it has been prepared in cooperation with the governments of Newfoundland and Labrador, Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Northwest Territories, and Yukon; Parks Canada Agency, Wildlife Management Boards, and Indigenous organizations as per section 66(1) of SARA and *l'Entente de collaboration pour la protection et le rétablissement des espèces en péril au Quebec* (Cooperation Agreement for the Protection and Recovery of Species at Risk in Quebec).

Success in the conservation of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this plan and will not be achieved by Environment and Climate Change Canada and the Parks Canada Agency, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this plan for the benefit of the Yellow-banded Bumble Bee and Canadian society as a whole.

Implementation of this management plan is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

[2] www.canada.ca/en/environment-climate-change/services/species-risk-act-accord-funding.html#2
[3] The Province of Quebec is not signatory of the Accord for the Protection of Species at Risk (1996). It does, however, cooperate with the federal government in the conservation of species at risk of common interest.

Acknowledgments

This management plan was prepared by Syd Cannings (Environment and Climate Change Canada, Canadian Wildlife Service (CWS) Northern Region), with the able and necessary assistance of a technical team made up of Julie McKnight (CWS Atlantic), Judith Girard and Elisabeth Shapiro (CWS Ontario Region), Marianne Gagnon and Audrey Robillard (CWS Québec Region), Yeen Ten Hwang (CWS Prairie Region), Nancy Hughes (CWS Northern Region), Eric Gross and Kim Dohms (CWS Pacific Region), Darien Ure (Parks Canada Agency), David McCorquodale (Cape Breton University), Michel Saint-Germain (Montréal Insectarium), Sheila Colla (York University), Cory Sheffield (Royal Saskatchewan Museum), Kirsten Palmier (University of Regina), Shelley Garland and Shelley Moores (Newfoundland and Labrador Fisheries and Land Resources), Courtney Baldo, Donna Hurlburt, and Mark McGarrigle (Nova Scotia Lands and Forestry), Maureen Toner (New Brunswick Energy and Resource Development), Garry Gregory (Prince Edward Island Communities, Land and Development), Nathalie Desrosiers and Isabelle Gauthier (Québec Ministère des Forêts, de la Faune et des Parcs), Colin Jones (Ontario Natural Resources and Forestry), Joanna Wilson (Northwest Territories Environment and Natural Resources), Megan Evans (Alberta Environment and Parks), Jennifer Heron (British Columbia Environment and Climate Change Strategy), and Tom Jung (Yukon Environment).

Other experts consulted include Nigel Raine (University of Guelph), Leif Richardson (University of Vermont, Xerces Society), and Lincoln Best (Consultant, @beesofcanada). Bonnie Fournier (Government of Northwest Territories) was kind enough to create the range map, and Sarah Johnson and Denis Doucet offered their fine photos. This management plan was based to a great extent on the recovery strategy for Gypsy Cuckoo Bumble Bee. Special thanks go to Kella Sadler (CWS Pacific Region) and Matthew Huntley (CWS National Capital Region) for their extensive guidance and comments on that document.

Acknowledgement and thanks are also given to all other parties that provided advice and input used to help inform the development of this management plan, including various Indigenous Organizations and individuals, provincial and territorial governments, other federal departments, landowners, citizens, and stakeholders.

Executive Summary

In May 2015, the Yellow-banded Bumble Bee (*Bombus terricola*) was assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Special Concern, owing to a large observed decline in abundance in southern Canada. It was added to Schedule 1 of the Species at Risk Act (SARA) in May 2018. This bee ranges across most of Canada south of treeline, from the southeastern Yukon and eastern British Columbia east to the island of Newfoundland.

The four main threats impacting the Yellow-banded Bumble Bee are: pathogen transmission and spillover from managed bumble bee populations in greenhouses; pollution (the use of insecticides, herbicides and fungicides in agriculture and silviculture); intensification of agriculture; and climate change (habitat shifting and alteration, and temperature extremes).

The Yellow-banded Bumble Bee also faces limiting factors. It requires a constant suite of floral resources to support colony growth: pollen and nectar need to be available throughout the growing season. Bumble bees have a type of sex determination that makes them extremely susceptible to extinction when population sizes are small.

The management objectives for the Yellow-banded Bumble Bee are to:

- Increase abundance of the species in parts of its Canadian range where it has declined, and maintain abundance in the remainder of its Canadian range.
- Maintain the distribution of the species throughout its known Canadian range.

Broad strategies and conservation measures to achieve the management objectives for the species are presented in section 6.

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1. COSEWIC* Species Assessment Information

Date of Assessment: May 2015

Common Name (population): Yellow-banded Bumble Bee

Scientific Name: *Bombus terricola*

COSEWIC Status: Special Concern

Reason for Designation: This bee has an extensive distribution in Canada, ranging from the Island of Newfoundland and the Maritime provinces, west to eastern British Columbia, and north into the Northwest Territories and extreme southwestern Yukon. Perhaps 50-60% of the global range of this species occurs in Canada. This species was historically one of the most common bumble bee species in Canada within its range. However, while this species remains relatively abundant in the northern part of its range, it has recently declined by at least 34% in areas of southern Canada. Causes for declines remain unclear, yet pesticide use, habitat conversion, and pathogen spill over from managed bumble bee colonies are suspected contributing factors.

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

COSEWIC Status History: Designated Special Concern in May 2015.

* COSEWIC (Committee on the Status of Endangered Wildlife in Canada)

2. Species Status Information

The International Union for Conservation of Nature (IUCN) has designated the Yellow-banded Bumble Bee (*Bombus terricola*) as Vulnerable, based on rangewide declines assessed as greater than 30% (Hatfield *et al.* 2015); however there are issues with how this assessment included the northern and western portions of the species' range, where no declines are documented.

In the Northwest Territories the Yellow-banded Bumble Bee is assessed as Not at Risk under the *Species at Risk (NWT) Act* (Northwest Territories Species at Risk Committee 2019). In Ontario, it is listed as Special Concern (2016) under the *Endangered Species Act, 2007* (ESA) (Ontario Natural Heritage Information Centre 2018). In Nova Scotia it is listed as Vulnerable (2017) under the Nova Scotia *Endangered Species Act* (Nova Scotia Endangered Species Act - N.S. Reg. 2017). The species has no status in British Columbia, Alberta, Saskatchewan, Manitoba, New Brunswick, Newfoundland and Labrador, or the Yukon.

In Quebec, the Yellow-banded Bumble Bee is not yet designated under the *Loi sur les espèces menacées ou vulnérables* (RLRQ, c E-12.01) (LEMV); however, this bee is on the list of species likely to be designated as threatened or vulnerable under the LEMV..

Table 1 summarizes the other, non-legal status designations assigned to the Yellow-banded Bumble Bee.

Table 1. Conservation status of the Yellow-banded Bumble Bee (Canadian Endangered Species Conservation Council 2016; British Columbia Conservation Data Centre 2019; Government of Northwest Territories 2020; NatureServe 2020).

Global Rank*	National Rank*	Sub-national (S) Rank*	BC List
G3G4	Canada (N5) United States (NU)	Canada: Yukon (S3), Northwest Territories (SU), British Columbia (S3S4), Alberta (S5), Saskatchewan (S5), Manitoba (S3S5), Ontario (S3S5), Quebec (S2), Labrador (SU), Newfoundland (S3S4), New Brunswick (S3?), Nova Scotia (S3), Prince Edward Island (S3) United States: Connecticut (S1), Georgia (SNR), Illinois (SX), Indiana (SH), Maine (SU), Maryland (S1), Massachusetts (S2S3), Michigan (S2S3), Minnesota (SNR), Montana (SNR), Nebraska (SNR), New Hampshire (SNR), New Jersey (SNR), New York (S1), North Carolina (S3S4), North Dakota (SNR), Ohio (SNR), Pennsylvania (SNR), Vermont (S2S3), Virginia (S1), Wisconsin (S1), Wyoming (SNR)	Blue List (Special Concern 2016)

*Rank 1– critically imperiled; 2– imperiled; 3- vulnerable to extirpation or extinction; 4- apparently secure; 5– secure; X – presumed extirpated; H – historical/possibly extirpated; NR – status not ranked; U – unrankable

3. Species Information

3.1. Species Description

The Yellow-banded Bumble Bee is a medium-sized bumble bee, with queens, reproductive males, and a smaller worker caste. They have a short face and tongue length relative to most other bumble bees. The upperside of much of the abdomen is black, but there is a distinctive, broad band of golden yellow hair across segments 2 and 3 (Figure 1). Segment 5 is black or pale yellow-brown.

The males are similar in colour to the females, although they usually have more yellow hairs on the face. They are intermediate in size between queens and workers, and have relatively short antennae (COSEWIC 2015). For more information on morphology, see Williams *et al*. (2014).

The Yellow-banded Bumble Bee was formerly considered conspecific with the Western Bumble Bee (*Bombus occidentalis*) but Bertsch *et al.* (2010) and Williams *et al.* (2012) reported mitochondrial CO1 sequences sufficiently divergent to consider the two separate species. Furthermore, Owen and Whidden (2013) found consistent morphological and molecular characters supporting two distinct species.

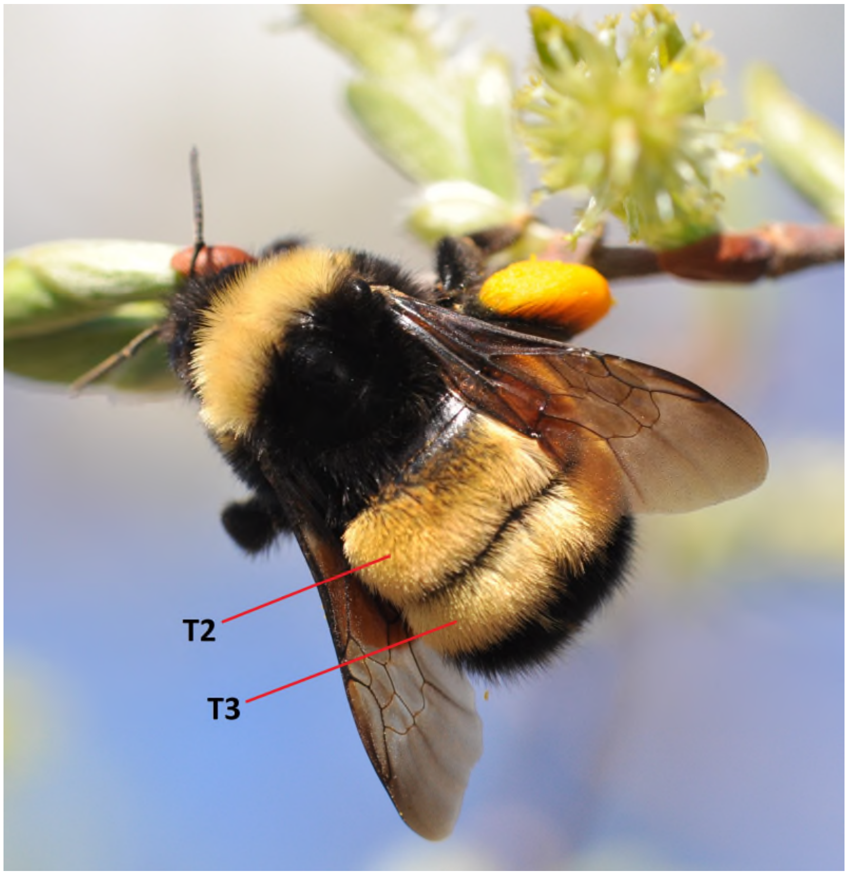

Figure 1. Queen Yellow-banded Bumble Bee on willow, Ontario. T2 and T3: Abdominal tergites 2 and 3. Photo: Sarah Johnson. Used with permission.

3.2. Species Population and Distribution

The Yellow-banded Bumble Bee occurs only in North America. It ranges from Georgia north to Labrador, and west through the northern United States and Canada to Montana, British Columbia (BC), the Northwest Territories (NT), and the southeastern Yukon (YT) (Figure 2). Its northern limit roughly follows latitudinal treeline. Earlier records from Alaska (e.g., as shown in COSEWIC (2015)) have now been reassessed, and the Yellow-banded Bumble Bee is no longer considered to be part of that state's fauna (Sikes and Rykken 2020). Approximately 50-60% of its global range is in Canada (COSEWIC 2015).

The Yellow-banded Bumble Bee is known to occur in every Canadian province and territory except Nunavut (NU) (COSEWIC 2015), although it may occur in the unsurveyed southwestern corner of that territory (Figure 2). In the YT it is absent west of the Mackenzie Mountains, but it ranges extensively into the central part of BC (COSEWIC 2015).

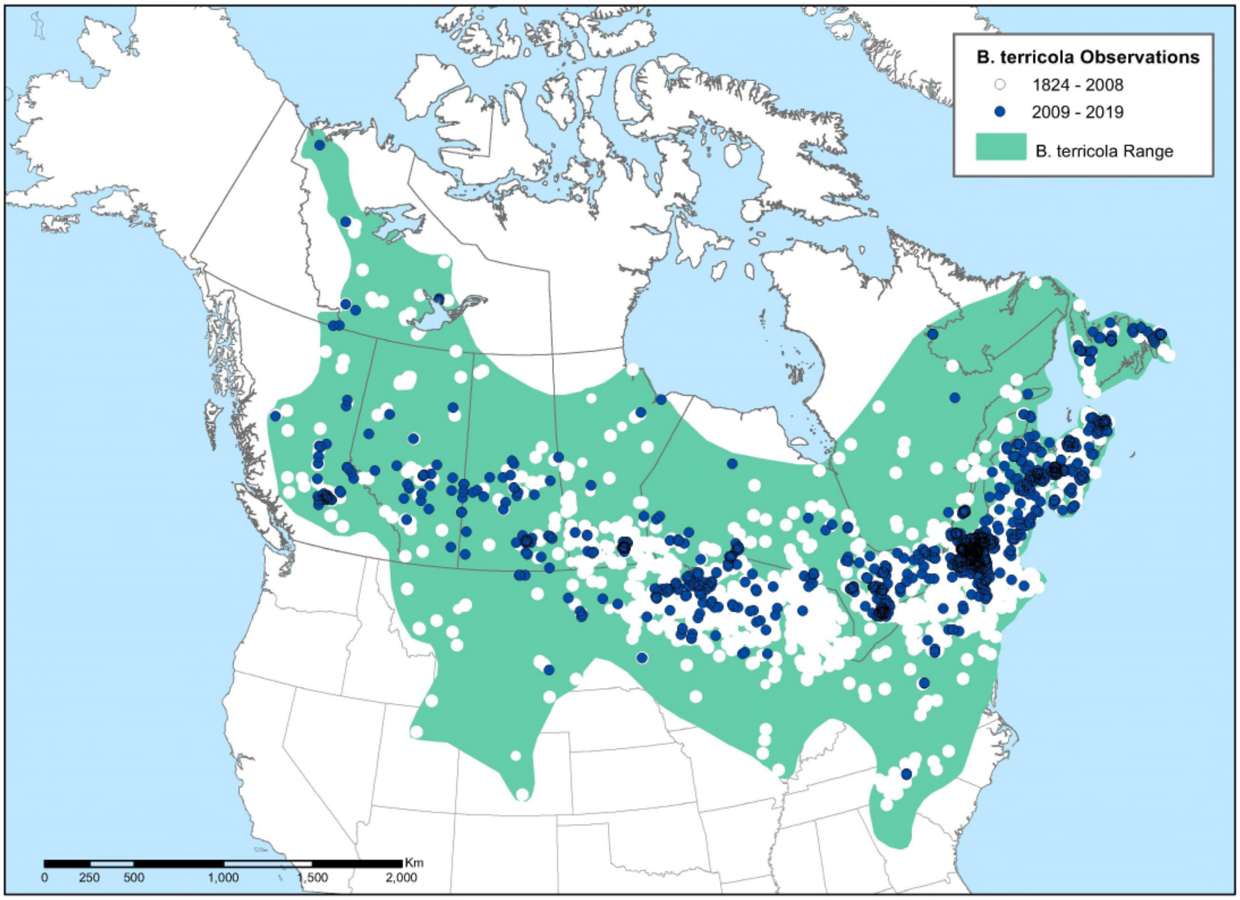

Figure 2. Global range of Yellow-banded Bumble Bee. Observations (museum specimens and photographs confirmed in iNaturalist (2020) and Bumble Bee Watch (2019)) since 2009 are represented by dark blue dots. Northern limit of range uncertain, especially in central Canada. Data from L. Richardson and S. Cannings, map by B. Fournier (Government of Northwest Territories). Dataset is not comprehensive; some specimens (e.g. those in Prescott et al. 2019) were not included because the data was received after December 2019.

The Yellow-banded Bumble Bee was once one of the most common bumble bees of eastern and boreal Canada but its abundance south of the boreal regions began to decline in the early 1990s. Trend data are imperfect, but the best available data set shows relative abundance (Yellow-banded Bumble Bee relative to all bumble bees) at 10 regional sites across southern (sub-boreal) Canada (from 100 Mile House, BC, and Edmonton east through Ottawa and Montreal to the Atlantic Provinces) declined from 20% before 2004 to 4% in the decade 2004-2013 (Table 2 in COSEWIC 2015). In general, the Yellow-banded Bumble Bee has maintained its broad range despite the declines; the one Canadian exception may be extreme southwestern Ontario (i.e. south and west of Kitchener-Waterloo), where the species was always uncommon and few if any have been located since 2004 (Colla and Dumesh 2010; COSEWIC 2015, iNaturalist 2020).

In the north (e.g. the boreal forest), there are few collections previous to 2010, so trends in abundance are difficult to detect; however, the species is relatively common in recent surveys there (Cory Sheffield, pers. comm. 2018; Northwest Territories Species at Risk Committee 2019). It is also likely still common in the more remote areas of eastern Canada, as evidenced by its abundance at higher elevations in New Hampshire (Tucker and Rehan 2017).

3.3. Needs of the Yellow-banded Bumble Bee

The Yellow-banded Bumble Bee is a habitat generalist. It is found in a wide variety of open habitats, including meadows within coniferous, deciduous, and mixed-wood forests and woodlands; taiga; prairie grasslands; riparian zones; urban parks, gardens, and agricultural areas; and along roadsides (COSEWIC 2015). In southern Ontario, Yellow-banded Bumble Bee habitat is positively correlated with coniferous forest and is negatively correlated with agricultural pesticide use, European Honey Bee colonies, roads, and high summer temperatures (Liczner and Colla 2020).

Like other bumble bees, the Yellow-banded Bumble Bee is a generalist pollen forager and visits the flowers of a wide variety of plant species, from willows to raspberries to clovers (see Appendix A). It is short-tongued, so requires relatively shallow flowers for pollen gathering, but can rob nectar from deeper flowers by chewing through the flower's wall (Evans *et al.* 2008). Because it is a colonial species that is active throughout the growing season, its primary requirement is a series of pollen and nectar sources throughout the spring and summer (Goulson 2010). The active season is approximately April to September in the southern part of the Yellow-banded Bumble Bee's range and May-August in the northern part. In southern Ontario, the amount of foraging resources was consistently the most important variable in Yellow-banded Bumble Bee habitat selection (Liczner and Colla 2020). Many of the flowers used are considered invasive or exotic weeds in disturbed habitats (e.g., White Sweet-clover, *Melilotus alba*; Common Dandelion, *Taraxacum officinale*; White Clover, *Trifolium repens*). In fact, Gibson *et al.* (2019) found that in southern Ontario, Yellow-banded Bumble Bees preferred to forage on invasive Tufted Vetch (*Vicia cracca*) and other exotic members of the pea family.

Geographic availability of floral resources within home range areas may vary both within and among years (e.g., blueberries (*Vaccinium spp.)* may have abundant blooms one spring, but not the next). Given this variability, this species requires a variety of floral sources at a landscape scale.

In the late summer and early autumn (late July in the north, August and early September in the south), reproductive adult females and males emerge from the nest and leave to find mates. Mated females disperse to select an overwintering site, travelling an unknown distance to do so. Like other bumble bees, Yellow-banded Bumble Bee males and workers die at the onset of cold weather, as do the queens of the previous summer; thus the colonies are only active for one season (Williams *et al.* 2014, COSEWIC 2015). The specific overwintering habitats of Yellow-banded Bumble Bee queens are unknown (Liczner and Colla 2019), but bumble bees typically burrow 2-15 cm deep in loose soil or rotting logs (Macfarlane 1974; Benton 2006; Liczner and Colla 2019). Because the queens do not survive more than one winter there is no overwintering site fidelity by individuals.

Dispersal occurs primarily in spring by queens while searching for suitable nest sites (Goulson 2010). There is evidence that bumble bees are able to disperse relatively long distances, at least between 2.6 and 10 km from the colony of origin (Stout and Goulson 2000, Kraus *et al*. 2008, Lepais *et al*. 2010).

Yellow-banded Bumble Bees nest underground (Laverty and Harder 1988), often in abandoned rodent or rabbit burrows (Plath 1927; Hobbs 1968; Macfarlane 1974; Colla and Dumesh 2010).

3.4. Limiting Factors

Bumble bees have a type of sex determination that makes them extremely susceptible to extinction when effective population sizes are small (Zayed and Packer 2005). As numbers decline, more and more females develop as sterile males instead. In practical terms, if a bee population decreases to a few reproducing individuals, it is certain to become locally extirpated even under favourable environmental conditions unless its number increases within a few generations. There are no data on the importance of this issue in Canadian Yellow-banded Bumble Bee populations at present, but (for example) it would probably limit the ability of the species to recolonize extreme southwestern Ontario.

A genetic study of the Yellow-banded Bumble Bee in southeastern Canada has shown that it has limited genetic diversity since a population crash after the last Ice Age resulted in inbred populations. The population is now experiencing inbreeding again where its populations have recently declined, which may contribute to further declines (Kent *et al.* 2018).

4. Threats

4.1. Threat Assessment

The Yellow-banded Bumble Bee threat assessment (Table 2) is based on the International Union for Conservation of Nature–Conservation Measures Partnership (2006) (IUCN-CMP) unified threats classification system (Salafsky *et al.* 2008; Master *et al*. 2009). The calculated overall threat impact is High-Medium.

Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational). Limiting factors are not considered during this assessment process. For purposes of threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of the threats are presented in the Description of Threats section (4.2).

Table 2. Threat assessment for the Yellow-banded Bumble Bee across its range in Canada, based on COSEWIC (2015).

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
1	Residential & commercial development	Negligible	Negligible	Slight	High	Urban development is limited in scope within range; however, cumulative impacts of housing and industrial development surrounding the urban centres can result in complete loss of local habitat.
1.1	Housing & urban areas	Negligible	Negligible	Negligible	High	Urbanization has the potential for greatly reducing floral resources, although bee-friendly green spaces may allow bees to still live within cities.
1.2	Commercial & industrial areas	Negligible	Negligible	Slight	High	Commercial and industrial development may have a greater impact than housing/urban development, but see comments above.
1.3	Tourism & recreation areas	Negligible	Negligible	Negligible	High	Some types of recreational development could cause habitat to be lost, though other developments can be beneficial.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
2	Agriculture & aquaculture	Low	Small	Serious	High	Habitat loss as a result of agricultural expansion and intensification.
2.1	Annual & perennial non-timber crops	Low	Small	Serious	High	The increased reliance on intensive agriculture (decreased ‘edge meadows’ around planted fields) has reduced foraging habitat for bumble bees.
3	Energy production & mining	Negligible	Negligible	Extreme-Serious	High	
3.1	Oil & gas drilling	Negligible	Negligible	Negligible	High	Could degrade habitat in short term, but could also result in increase in flowers.
3.2	Mining & quarrying	Negligible	Negligible	Extreme-Serious	High	Some long-term loss of habitat, but some could result in longer term increase in edge habitat
4	Transportation & service corridors	Negligible	Negligible	Negligible	High	
4.1	Roads & railroads	Negliglible	Negligible	Negligible	High	Loss of habitat in travelled portion of road; increased mortality from collisions with cars; benefit from increased flowers in roadside rights-of-way
7	Natural system modifications	Unknown	Small	Unknown	High	
7.1	Fire & fire suppression	Unknown	Small	Unknown	High	Fire is beneficial to bumble bee populations; thusfire suppression is undoubtedly detrimental in longer term.
7.2	Dams & water management/use	Negligible	Negligible	Extreme	High	New hydro projects flood valleys, and dams can also eliminate natural seasonal fluctuations of water levels in floodplains, reducing riparian meadows
8	Invasive & other problematic species & genes	Medium-Low	Large-Restricted	Moderate-Slight	High	Primarily the effects of pathogen spillover from greenhouse operations.
8.1	Invasive non-native/alien species	Medium-Low	Large-Restricted	Moderate-Slight	High	Problematic pathogens appear to be largely native in origin (see threat 8.2), but over much of the Yellow-banded Bumble Bee’s range are transmitted by non-native Common Eastern Bumble Bees (*B. impatiens*). European Honey Bees can transmit pathogens, and can compete with native bees when kept at high densities. The introduction and use of Common Eastern Bumble Bee for pollination services outside its natural range (e.g. in Atlantic Canada and BC) may result in competition for floral resources and nesting habitat.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
8.2	Problematic native species	Medium-Low	Large-Restricted	Moderate-Slight	High	Native pathogens are a major threat, including pathogen spillover from greenhouses (managed populations of Common Eastern Bumble Bee).
9	Pollution	Medium-Low	Restricted-Small	Serious	High	Insecticides can be directly detrimental. Herbicides reduce floral resources for all bees. Fungicide effects unknown, but implicated in increasing susceptibility of bumble bees to pathogens.
9.3	Agricultural & forestry effluents	Medium-Low	Restricted-Small	Serious	High	Persistent effects from chronic exposure to neonicotinoid insecticides lead to colony failure. Fungicides are implicated in the prevalence of *Varimorpha*; the concentration of a widely-used fungicide, chlorothalonil, is the best predictor of *Varimorpha* abundance. Widespread herbicide use (especially in conjunction with genetically modified crops) kills flowering plants within and adjacent to crops, and thus reduces floral resources for bees. Herbicides also widely used in reforestation.
11	Climate change & severe weather	Low	Pervasive	Slight	High	Primarily a decline in climate envelope along southern edge of its range.
11.1	Habitat shifting & alteration	Low	Pervasive	Slight	High	Climate envelopes shifting north. Bumble bees are losing southern portions of their ranges but not moving correspondingly north; attributed to climate warming. Bees also may be affected by mismatch in timing of active period with flowering plants.
11.2	Droughts	Unknown	Unknown	Unknown	High	Increased drought predicted in some regions; reduces floral resources
11.3	Temperature extremes	Low	Small	Slight	High	Research in Europe attributes loss of southern portion of ranges to increasing summer extreme heat events.

[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 threat is based on Severity and Scope rating 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% declines), 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 timeframe (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** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to occur within a 10-year or three-generation timeframe. 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.

4.2. Description of Threats

The Yellow-banded Bumble Bee is thought to be impacted by four primary threats (Table 2 above): 1) invasive non-native/alien species (e.g. Common Eastern Bumble Bee outside of its native range and European Honey Bee) and problematic native species (pathogen spillover from greenhouse bumble bees); 2) pollution (agricultural and silvicultural pesticides); 3) habitat loss from cropland expansion and intensification, and 4) climate change and severe weather (habitat shifting and alteration, temperature extremes). Threats are discussed in more detail below, grouped under the IUCN-CMP primary threat categories, in decreasing order of impact.

Invasive and Other Problematic Species and Genes (Threat 8)

<u>Invasive non-native/alien species (8.1) and Problematic native species (8.2)</u>

The introduction and/or spread of pathogens from commercially-raised bumble bees and European Honey Bees, and the accidental release of non-native bumble bees are apparently direct, serious threats to the Yellow-banded Bumble Bee. While no definitive experiments have been made to confirm this, several lines of correlative evidence point to pathogens as the primary cause of the decline in this species.

Parasites and pathogens of bumble bees

The prevalence of the microsporidian *Varimorpha (=Nosema) bombi* (a single-celled fungal parasite) in North American bumble bees increased dramatically from low detectable frequency in the 1980s to significantly higher frequency in the mid- to late-1990s, corresponding to a period of reported massive infectious outbreak of *V. bombi* in commercial bumble bee rearing stocks in North America (Cameron *et al.* 2016). Although *V. bombi* is native to North America, it has been postulated that a novel strain was imported from Europe about this time; however genetic evidence to date does not support this (Cameron *et al.* 2016; Brown 2017). *Varimorpha ceranae*, a prevalent pathogen associated with managed European Honey Bees, has also been detected in bumble bees worldwide, though the impact of this pathogen on bumble bees remains unclear and requires further investigation (Goblirsch 2018).

Studies have shown the parasites *Crithidia*[4] *bombi, C. expeoki* and *V. bombi* can have a potentially devastating effect on bumble bee colonies (Brown *et al.* 2000, 2003; Otti and Schmid-Hempel 2007, 2008; van der Steen 2008). These parasites are found in a variety of bumble bee species (Macfarlane 1974; Macfarlane *et al.* 1995; Colla *et al.* 2006). However, *V. bombi* infection rates and infection intensities were significantly higher in the Western Bumble Bee (the Yellow-banded Bee's closest relative), than they were in bumble bees with stable populations, such as the Common Eastern Bumble Bee (*B. impatiens*) and the Two-form Bumble Bee (*B. bifarius* [now considered to be *B. vancouverensis*] (Cameron *et al*. 2011). Similar trends were seen in Yellow-banded

[4] *Crithidia* are a group of single-celled, trypanosomatid parasites

Bumble Bees and Rusty-patched Bumble Bees, but small sample sizes precluded statistical analyses (Cameron *et al*. 2011). A recent genetic study of the Yellow-banded Bumble Bee revealed activation of immune system function in southern populations that had experienced declines, indicating possible “novel pathogen pressures” (Kent *et al.* 2018).

The rapid rise in *N. bombi* infection in commercial bumble bees, the coincident decline in the Yellow-banded Bumble Bee, and the fact that these pathogens are more prevalent in Yellow-banded Bumble Bees relative to healthy species have together caused pathogen spillover to be cited as one of the primary causes of the declines of the Yellow-banded Bumble Bee (Thorp and Shepherd 2005; COSEWIC 2010; Cameron *et al.* 2011; Szabo *et al.* 2012; Graystock *et al.* 2016; all cited in Colla 2017; Arbetman *et al.* 2017). Pathogen spillover occurs when managed populations of bees introduce pathogens to wild populations or amplify pathogens (spillback) that may have been naturally in lower abundances (Power and Mitchell 2004; Graystock *et al.* 2016). In Canada, the use of infected commercial bumble bees for greenhouse pollination is known to cause pathogen spillover into populations of wild bumble bees foraging near those greenhouse operations (Colla *et al.* 2006; Otterstatter and Thomson 2008). However, there is much to learn about the effects of pathogen spillover on wild bumble bee populations, and new pathogens are still being discovered (K. Palmier, pers. comm. 2020). See also section on Pollution (Threat 9, below) for apparent interactions between fungicides and pathogen prevalence.

European Honey Bees as vectors of pathogens and viruses

European Honey Bees appear to be another vector for the transmission of pathogens to wild bumble bees. Graystock *et al.* (2014) showed that, in Great Britain, the prevalence of *C. bombi* was 18% greater in bumble bees near an apiary than in those farther away from it. There is also increasing evidence that a number of European Honey Bee pathogens are transferable to bumble bees (Plischuk *et al*. 2009; Meeus *et al.* 2011; Peng *et al.* 2011; Graystock *et al.* 2013). Under controlled conditions, *V. ceranae*, a common parasite of European Honey Bees, produced fewer spores in bumble bees than in European Honey Bees but exhibited greater virulence, reducing survival by 48% and having sublethal effects on behaviour (Graystock *et al*. 2013). The potential impact of European Honey Bees as vectors of pathogens is unknown among North Amercian species of bumble bees.

European Honey Bees that are infected with *Deformed wing virus* through the Varroa Mite *(Varroa destructor)* during pupal stages develop into adults showing wing and other morphological deformities. Researchers in Germany and the United Kingdom have found this European Honey Bee virus in deformed individuals of Buff-tailed Bumble Bee (*Bombus terrestris*) and *B. pascuorum* (Genersch *et al.* 2005; Fürst *et al.* 2014), and recent studies in Vermont have found *Deformed wing virus* and *Black queen cell virus* in bumble bees collected near European Honey Bee apiaries (Alger *et al*. 2019). Because the Varroa Mite is widespread in Canada (Ontario Ministry of Agriculture, Food and Rural Affairs 2019, Canadian Association of Professional Apiculturalists 2020), *Deformed wing virus* may pose a serious potential threat to Canadian bumble bee populations.

Competition with European Honey Bees

European Honey Bees also compete directly with bumble bees when pollen and nectar resources are not abundant. Pollen can be a limiting resource; in the absence of European Honey Bees, native bees can remove 97-99% of the available pollen daily (Schlindwein *et al.* 2005, Larsson and Franzen 2007). One standard apiary of 40 European Honey Bee colonies can remove 400 kg of pollen during three summer months in wildlands (Winston 1987; Seeley 1995; Cane and Tepedino 2016). Cane and Tepedino (2016) point out that this amount of pollen would produce 4 million (range 3.7-12 million) individuals of an average leafcutter bee (*Megachile rotunda*). Henry and Rodet (2018) found that high-density beekeeping (greater than 14 colonies/km^2) triggers foraging competition that depresses both the occurrence (−55%) and nectar foraging success (−50%) of local wild bees. However, Mallinger *et al.* (2018) caution that more competition studies that include measures of wild bee reproductive success are needed to quantify ongoing effects.

Competition with exotic bumble bees

The introduction and use of the Common Eastern Bumble Bee for pollination services in Canada may further impact the Yellow-banded Bumble Bee in the southern parts of its range. The Common Eastern Bumble Bee may out-compete some native bee species for nesting habitat or forage resources, and may serve as a source for pathogens or diseases. The recent establishment of wild, exotic populations of Common Eastern Bumble Bee in Atlantic Canada, southeastern Alberta, and southwestern British Columbia (Palmier and Sheffield 2019) has likely had a negative impact on native species, as has been documented in other parts of the world (Williams and Osborne 2009).

Pollution (Threat 9)

Agricultural and forestry effluents (9.3)

It has long been known that pesticides can have negative impacts on bees (e.g., Johansen and Mayer 1990; NRC 2007). Although the recent focus has largely been on neonicotinoid insecticides, other insecticides, herbicides and fungicides have also been tied to bumble bee declines. The queens and workers of Yellow-banded Bumble Bees are exposed to pesticides while they forage, and while they burrow into the soil to expand nest sites.

Neonicotinoid insecticides

Around the time when the declines of bumble bees in the subgenus *Bombus* were observed in North America, the neonicotinoid insecticide imidacloprid was registered for use in the United States and Canada (1994 and 1995 respectively: Cox 2001). Neonicotinoids can pose a particularly severe threat to bees because they can be harmful even at concentrations in the parts-per-billion (ppb) range (Marletto *et al.* 2003). These pesticides are systemic, travelling throughout plant tissues and integrating with pollen and nectar. They are routinely used on golf courses and agricultural lands (Sur and Stork 2003). They are also used prophylactically; that is, they are being applied even if there is no apparent insect outbreak needing attention (van der Sluijs *et al*. 2014). In Quebec, Labrie et al. (2020) found that preventative neonicotinoid seed treatments in field crops are useful in less than 5% of cases, and suggest that integrated pest management solutions would likely offer an effective alternative to these practices (Labrie et al. 2020).

In 2012 in the Canadian prairie provinces, neonicotinoids were applied on about 11 million hectares (44% of the cropland; Main et al. 2014). In southern Quebec, about 600,000 hectares of corn and soybean cultures are treated annually with neonicotinoids (Giroux 2019). In Ontario, about 1.2 million hectares of soybean and corn crops were treated with neonicotinoids in 2016-2017 (Ontario Ministry of Environment, Conservation and Parks 2018). At present, most application is via a seed coating, but foliar application also occurs.

The effects of imidacloprid are not lethal to individual bumble bees when used as directed (e.g., Tasei *et al.* 2001), but colonial insects such as bumble bees can be negatively impacted by cumulative sub-lethal effects of this and other pesticides. In fact, recent studies have shown that chronic (i.e. 1-4 weeks) exposure to neonicotinoid pesticides can have significant effects on bumble bees at field-realistic exposure levels (Pisa *et al.* 2014; van der Sluijs *et al*. 2014; Crall *et al*. 2018; Raine 2018): bees suffered impaired learning and short-term memory (Stanley *et al.* 2015a); decreased foraging performance (Feltham *et al.* 2014; Gill and Raine 2014; Stanley *et al.* 2015b; Stanley *et al.* 2016); reduced queen production (Whitehorn *et al.* 2012); and ultimately, colony failure (Bryden *et al.* 2013).

Other neonicotinoids such as thiamethoxam and clothianidin also have effects on bumble bees, although these effects are not identical. Moffat *et al.* (2016) found that both thiamethoxam and imidacloprid reduced “colony strength” (number of live bees), but clothianidin did not. However, although Arce *et al*. (2017) found only subtle, mixed effects by clothianidin on worker behaviour (e.g. foraging frequency, pollen load size), they did find reduced numbers of adult bees at colonies exposed to the insecticide.

Neonicotinoid exposure in concert with other threats can also have significant deleterious results. In a study on the Common Eastern Bumble Bee, imidacloprid exposure followed by an immune challenge significantly decreased survival probability relative to control bees (Czerwinski and Sadd 2017).

The effects of neonicotinoids on pollinators have been reviewed by Health Canada’s Pest Management Regulatory Agency (PMRA) and three re-evaluation decisions for thiamethoxam, clothianidin, and imidacloprid were released in April 2019 (Health

Canada 2019a, 2019b, 2019c); the detailed regulation changes can be found in the cited documents. A summary is provided as well (Health Canada 2020). In general, application of these neonicotinoids will be cancelled or restricted for certain uses, especially those related to foliar or soil applications on fruits, nuts, ornamentals, and outdoor-grown fruiting vegetables; cereal and legume seed-treatment uses will receive additional label instructions only. The required mitigation measures must be implemented on all product labels no later than 11 April 2021 (Health Canada 2020). Further regulation changes were made in re-evaluation decisions made in the spring of 2021 (Health Canada 2021a, 2021b, 2021c). In general, application of these neonicotinoids will be cancelled or restricted for certain uses, especially those related to foliar or soil applications on fruits, nuts, ornamentals, and outdoor-grown fruiting vegetables; and some corn and legume seed-treatments. Other uses will receive additional label instructions. The changes made in the 2021 re-evaluations will take effect in the spring of 2023.

These new regulations from PMRA will thus not end the use of neonicotinoid pesticides in Canada. Future restrictions related to their effects on aquatic invertebrates are under consideration (Health Canada 2020); the results of studies and consultations were scheduled to be released in the spring of 2021, and probably will not take effect for a few years.

In 2015, Ontario brought in new regulations designed to reduce the acreage planted with neonicotinoid-treated corn and soybean seed by 80%by 2017. By 2018, however, reductions of only 37.5% relative to 2014 had been achieved (Ontario Ministry of the Environment, Conservation and Parks 2019; Raine, pers. comm. 2019).

Other insecticides

Sulfoxamine-based insecticides are the most likely successors to neonicotinoids, but there are few studies into their sub-lethal effects on pollinators. A recent study, however, found that bumble bee colonies exposed to sulfoxaflor produced significantly fewer workers than unexposed controls, and ultimately produced fewer reproductive offspring (Siviter *et al.* 2018).

Chlorantraniliprole is another insecticide recently approved for use in Canada as a seed treatment of corn that will at least partially replace the use of neonicotinoid insecticides. Although Health Canada (2016) determined that as a seed coat it presented a "negliglible risk to … bees," research has shown that low-level, chronic oral exposure via pollen lead to lethargic behaviour in bumble bee workers and drones (Smagghe *et al.* 2013).

Tebufenozide is an insect growth regulator insecticide used for spruce budworm control in eastern Canada. A study on European Honey Bees found that those treated with field-realistic dosages of tebufenozide did not perform as well as untreated bees in learning experiments (Abramson *et al.* 2004). However, Smagghe *et al.* (2007) found no negative effects of tebufenozide on adult survival, nest reproduction, and larval growth in *Bombus terrestris*.

Herbicides

The use of glyphosate as a broad-spectrum, systemic herbicide has increased 15-fold since the mid-1990s, when genetically-engineered herbicide-tolerant crops were introduced (Benbrook 2016). In Canada, the great majority of canola, soybean, and corn crops are now planted with genetically-engineered herbicide-tolerant varieties (Wilson 2012). Generally considered to have low toxicity to terrestrial insects, there are indications that glyphosate may have sub-lethal effects on bees (Helmer *et al.* 2014; Herbet *et al.* 2014; Balbuena *et al*. 2015; Vázquez 2018), impair brood thermoregulation (Weidenmüller *et al.* 2022) and increase susceptibility to infection by pathogens (Motta *et al*. 2018). The co-formulants (surfactants) of herbicides may also harm bees by interfering with their breathing system when the herbicide directly contacts them (Straw *et al*. 2021).

More importantly, however, the intensive and extensive use of glyphosate and other herbicides has undoubtedly resulted in a great reduction in floral resources in treated landscapes, and has thus likely contributed to reduced bumble bee colony and reproductive success. In the prairie provinces, over 30% of agricultural land was treated with herbicides in 2011 (Agriculture and Agri-foods Canada 2016). Because of increased genetic resistance to glyphosate and the lack of new herbicides, Health Canada and the Canadian Food Inspection Agency have recently approved genetically engineered crops that are resistant to the herbicides 2,4-D and dicamba (Canadian Biotechnology Action Network 2018).

In Canada, an average of 116,000 hectares of publicly-owned forest lands are treated with glyphosate herbicides annually; when the area of privately-owned forest lands are considered, the total area treated may be closer to 150,000 ha/yr, about one-third of the area cut (ForestInfo 2018). Quebec banned the use of herbicides in forests in 2001. The use of glyphosate in Alberta silviculture has been increasing (Thompson and Pitt 2011). There is no use of herbicides for forestry north of 60°N (National Forestry Database 2019).

Fungicides

There is increasing evidence suggesting that fungicides may have detrimental effects on bees. Bernauer *et al.* (2015) demonstrated that colonies of the Common Eastern Bumble Bee produced fewer workers, had less bee biomass, and had smaller mother queens following exposure to chlorothalonil, a widely used fungicide on crop and ornamental plants. Fungicides may also interact with other bumble bee threats; in fact, a study by McArt *et al.* (2017) found that the level of chlorothalonil in the regional (county) environment was the strongest predictor of the prevalence of the pathogen *Varimorpha bombi* in four declining bumble bee species, including the Yellow-banded Bumble Bee.

The use of fungicides is widespread; Pettis *et al.* (2013) found that 100% of European Honey Bee-collected pollen in agricultural landscapes contained fungicide residue.

Agriculture and Aquaculture (Threat 2)

<u>Annual and perennial non-timber crops (2.1)</u>

Habitat loss as a result of agricultural expansion and intensification (i.e., reduction of non-crop habitats in farmland) is a threat in parts of southern Canada. The Yellow-banded Bumble Bee requires large amounts of nectar and pollen over the entire flight season. Over the past few decades, the increasing practice of planting crops to edge of fields, with little or no adjacent hedgerow or meadow habitat, has resulted in decreased quality foraging habitat for bumble bees globally (e.g., Kosior *et al.* 2007), and probably has had similar impact in Canada (Grant and Javorek 2011). In fact, cropland in Canada has increased 6.9% to 377,976 km^2 in 2011-2016 (Statistics Canada 2017). This total area is about 10% of the Canadian range of the Yellow-banded Bumble Bee; the area lost to the bee during that 5-year period was thus on the order of 0.7% of its range. Even where intensive crops support bees (e.g. blueberries), these crops generally bloom only for a short time, and bumble bees cannot thrive without a diversity of plants in surrounding areas that bloom through the growing season. Although the loss of Yellow-banded Bumblebee habitat due to agricultural intensification is serious where it occurs, the impact of the threat is still considered low, because of the small proportion of the range affected by it. The impact of agricultural expansion varies across the range; for example, the Yellow-banded Bumble Bee was never common in extreme southwestern Ontario and the dry, southern Prairies, but was abundant in other parts of southern Ontario and the aspen parklands of the Prairies.

Climate Change and Severe Weather (Threat 11)

Climate change is a threat to bumble bees worldwide (Williams and Osborne 2009; Soroye *et al.* 2020). In general, bumble bees are cool-adapted species that live in temperate areas. Kerr *et al.* (2015) assembled long-term bumble bee data for Europe and North America and showed that, as climate warms, bumble bees are disappearing from the southern edges of their ranges but not correspondingly shifting northward at the northern edges. These effects were independent of changing land uses or pesticide applications. Across a range of climate change scenarios and assumptions about the capacities of bumble bees to disperse into new areas, range declines are expected to continue and even to accelerate among North American bumble bees (Sirois-Delisle and Kerr 2018; Soroye *et al*. 2020). Bumble bee species with narrow climatic tolerances are also shown to be more vulnerable to extrinsic threats (Williams *et al.* 2009). Rasmont and Iserbyt (2012) attribute some declines in European bumble bees to increasing occurrences of extreme heat waves. There are no direct estimates for the Yellow-banded Bumble Bee, but climate change scenarios modelled by Rasmont *et al.* (2015b) predict that the climatic niche of its close relative the Buff-tailed Bumble Bee will decline by 34 to 71% by the end of this century.

Pollen serves as the only source of protein for developing larvae. Recent research has shown that the rise in carbon dioxide levels in the atmosphere has led to a 33% decline in protein content in Canada Goldenrod (*Solidago canadensis*) pollen since the beginning of the industrial era, and that a similar drop is expected in most flowering plant species (Ziska *et al*. 2016).

Longer growing seasons can be problematic for bumble bees in a number of ways. Ogilvie *et al.* (2017) studied the effects of growing season length in the United States Rocky Mountains, and found that longer seasons had a negative effect on the interannual abundance of three species of bumble bees. This result was attributed to more days of low flower availability within the longer growing season.

Climate change can also disrupt the phenology of bumble bees during the winter. In areas of moderate winters (such as those in the southern United Kingdom), bumble bees can become winter-active, especially if autumn temperatures are above normal (Owen *et al.* 2013). Although the Buff-tailed Bumble Bee (a close relative of the Yellow-banded Bumble Bee) workers can rapidly adapt to cold winter temperatures while active, they will die if they remain outside the colony overnight when the temperatures fall to about -10°C. This is not anticipated to be a major threat to Yellow-banded Bumble Bees in Canada, since they are not present in areas with really moderate winters.

Threats with an Unknown Impact

Fire and fire suppression (7.1)

Fire and fire suppression are difficult to score together. Fire is a short- and medium-term benefit to bumble bee populations (Galbraith *et al*. 2019), so fire suppression that maintains shady, flower-poor forests is a threat. However, the severity of this threat is difficult to measure, so is scored Unknown. The scope is also difficult to characterize; forest fires have a relatively small footprint over a ten-year period and fire suppression prevents burning over an unknown area in that time. Fire suppression is pursued less vigorously in the northern, more remote areas of the boreal region than it is in the south.

Negligible Threats

Housing and urban areas (1.1) and Commercial and industrial areas (1.2)

Habitat loss as a result of urbanization is a threat in parts of southern Canada; these threats are scored as negligible only because they occur primarily in a relatively small portion of this species’ large range. Although some development (e.g. suburban landscaping) might include an increase in the amount of floral resources for bumble bees, other urban, industrial and agricultural development virtually eliminates these resources.

For more discussion of other threats with a negligible impact (Power generation and mining, Transportation Corridors), see comments in Table 2 and COSEWIC (2015).

5. Management Objective

The Yellow-banded Bumble Bee was assessed by COSEWIC as Special Concern because of large declines in abundance in southern portions of its range in Canada (primarily those regions east of the Rocky Mountains and south of the boreal forest). Nevertheless, the species remains common in the northern (boreal) parts of its range (Cory Sheffield, pers. comm. 2018; Northwest Territories Species at Risk Committee 2019), and maintains a broad distribution in Canada (COSEWIC 2015).

The management objectives for the Yellow-banded Bumble Bee in Canada are to:

- Increase abundance of the species in parts of its Canadian range where it has declined, and maintain abundance in the remainder of its Canadian range.
- Maintain the distribution of the species throughout its Canadian range.

The Yellow-banded Bumble Bee has experienced declines that are probably primarily the result of pathogen spillover and spillback from managed bumble bee populations in greenhouse operations, and from an increase in pesticide use over the last three decades (COSEWIC 2015). Threats also include climate change and habitat loss within farmland. Except perhaps for climate change, these threats are most widespread in southern Canada, where declines have been most clearly documented. In northern Canada, the species appears to remain common (Northwest Territories Species at Risk Committee 2019). Therefore the management objective aims to halt the decline and then increase abundance in the southern part of the range where declines have occurred, while maintaining abundance in northern Canada. The distribution of the species has not shown a strong change over time, as it still appears to be present throughout much of its known range, except perhaps in southwestern Ontario. Therefore the management objective aims to maintain the known range of the species in Canada. However, there is some uncertainty around this objective with regards to the shifting climatic envelope of this species; climate warming ultimately may make southwestern Ontario unsuitable for this species.

The lack of effective monitoring of bumble bees is a stumbling block in their management. There are a number of information gaps in planning the conservation of the Yellow-banded Bumble Bee, including its former and present abundance throughout much of its range and the effects of the various identified threats. Maintaining its numbers and distribution will first require developing repeatable monitoring methods designed to measure an index of abundance, as well as widespread inventories designed to delineate its range limits.

Maintaining or increasing the current population will also require the mitigation or elimination of threats, especially those from managed populations of bumble bees and

European Honey Bees, and those from pesticides. Knowledge gaps around threats will have to be addressed. Increased outreach and communication with industry, landowners, and the general public will assist in achieving these objectives.

6. Broad Strategies and Conservation Measures

6.1. Actions Already Completed or Currently Underway

Actions contributing to Yellow-banded Bumble Bee management and recovery have been implemented by various government agencies, academic institutions, non-profit groups, and citizens within Canada (Table 3).

Table 3. Brief summary of conservation-related Yellow-banded Bumble Bee work ongoing or completed as of 2019.

Purpose	Jurisdiction	Conservation-related Action(s)
Surveying	Federal government, provinces and territories	• General bumble bee surveys being undertaken over much of populated Canada, for example: - Wildlife Preservation Canada (Guelph, Sudbury, Thunder Bay, Alberta, Ontario provincial parks) - York University (southern Ontario) - University of Calgary: south-central Alberta - University of Manitoba and Agriculture Canada, Brandon (Manitoba) - Various provincial/territorial/federal government surveys (e.g. in British Columbia, Alberta, Saskatchewan, Northwest Territories). - Montréal Insectarium (southern Québec, 2017-2019). - Zoo Ecomuseum - Saint Lawrence Valley Natural History Society, in collaboration with the Mohawk Council of Kanesatake and the Collection entomologique Ouellet-Robert, U. Montréal (Montreal region, 2017-2019). - CWS-Ontario pollinator surveys - CWS-North bumble bee surveys • Citizen Science initiatives, such as - Bumble Bee Watch (Bumble Bee Watch 2019): - iNaturalist (iNaturalist 2020); - Université Laval: Abeilles Citoyennes collects data on the distribution and abundance of pollinators in the main agricultural regions of Quebec. http://abeillescitoyennes.ca/Bioblitzes: bioblitzcanada.ca
Monitoring	YT, ON, NS, AB, SK, MB	• Roadside monitoring: Ongoing surveys modelled after the Breeding Bird Survey (Droege 2009;

Purpose	Jurisdiction	Conservation-related Action(s)
		McFarland et al. 2015): Underway in the Yukon (CWS-North) (10-17 surveys in 2017-2019), northwestern Ontario (29 in 2018), and Nova Scotia (2 in 2018) • Pollinator monitoring program underway (Ontario Ministry of Environment) in southwestern Ontario • Blue vane trap monitoring of pollinators in Peterborough, ON area (Ontario Ministry of Natural Resources and Forestry) • Alberta bumble bee survey (2018, and every 5 years following) (Alberta Native Bee Council). • Saskatchewan: long-term blue vane trapping program begun in Provincial Parks • Manitoba: monitoring program through University of Manitoba begun in 2019
Habitat restoration	Wildlife Preservation Canada	• Nest box program in Ontario

Stewardship	Health Canada	• Policy review regarding neonicotinoid pesticides and effects on pollinators recently completed (Health Canada 2019 a,b,c). Certain uses of neonicotinoid pesticides now banned, and other uses more strictly regulated. Policy review on effects on aquatic invertebrates still underway; this review may result in further restrictions on neonicotinoids.
	Environment and Climate Change Canada	• Species at Risk Partnerships on Agricultural Land (SARPAL) supports the agricultural sector to develop, test and implement beneficial practices that help recover and protect species listed under *SARA*
	Agriculture Canada	• Studies in MB regarding native bee needs in agricultural landscapes
	BC	• Four-year stewardship and outreach project in the southern interior, including landowner contact, surveys for bees, and recommendations for bumble bee management on the landowner's property.
	ON	• Ontario pollinator health initiatives (Ontario Ministry of Environment, Conservation and Parks 2019). The coating of corn and soybean seeds with neonicotinoid insecticides is being regulated, which will reduce the amount of neonicotinoids taken up by flowering plants in agricultural areas and their watersheds in the future.
	QC	• Under new Quebec government policy it is now mandatory to obtain an agronomic prescription to use seeds treated with neonicotinoids.
	York University	• York University Native Pollinator Research Lab: writing a document to guide a national pollinator conservation strategy
	City of Toronto	• Toronto Pollinator Protection Strategy: focuses on native bees.
	NWT	• Northwest Territories developing Beekeeping Best Management Practices; hosted Northern Bee Health Symposium in 2019
Research	• Wildlife Preservation Canada, York University	• Restoration research/conservation breeding for Yellow-banded Bumble Bee in Ontario (Wildlife Preservation Canada and York University)
	• University of Guelph	• Sublethal effects of pesticides (University of Guelph: e.g. Bryden et al. 2013; Gill and Raine 2014; Stanley et al. 2015a, 2015b; Stanley et al.

	• York University • University of Ottawa • University of Regina	2016;). • Conservation genetics (York University, e.g. Kent *et al.* 2018). • Utility and quality of data from Bumble Bee Watch for long term monitoring (York University) • Forage and dispersal distance research using radio tracking (York University) • Using trained dogs to find nests for monitoring (York University) • Social dimensions of pollinator conservation in Canada (currently analyzing surveys of farmers, the public, stakeholder consultation documents, ENGO narratives, etc. (York University) • Climate change and range loss in North American bumble bees (University of Ottawa) • Pathogen and microbiome research (University of Regina)
Outreach	Government of Northwest Territories Pollinator Partnership Canada (P2C) Wildlife Preservation Canada Ontario Nature Friends of the Earth Canada Habitat Stewardship Program (ECCC)	• NWT has produced a pocket field guide to bumble bees, a bee colouring book, and photographic key: https://www.enr.gov.nt.ca/en/services/insects-and-spiders/bees • Pollinator Partnership Canada (P2C) has a number of education initiatives, including Bee City Canada, a bumble bee brochure, technical guides for land managers and ecoregional planting guides for the general public. https://pollinator.org/canada • Wildlife Preservation Canada: outreach talks, handouts, workshops • Ontario Nature: outreach via emails and pollinator projects • Great Canadian Bumble Bee Count (public awareness) • Funding to the “bureau d’écologie appliquée” in Quebec, to produce a bumble bee identification key and a document to increase public knowledge of bumble bees at risk.

6.2. Broad Strategies

In order to achieve the management objective, conservation measures are organized under eight broad strategies (numbers refer to Conservation Measures Partnership (2016) Conservation Actions Classification (v2.0).

1. Land management
2. Species Management
3. Awareness raising
6. Conservation designation and planning
7. Legal and policy framework
8. Research and monitoring
9. Education and training
10. Institutional development

6.3. Conservation Measures

Table 4. Conservation Measures and Implementation Schedule

Conservation Measure	Priority[e]	Threats or Concerns Addressed	Timeline
Broad Strategy			
1. Land Management			
Minimize use of pesticides; develop, promote and follow best practices in the application of pesticides (insecticides, fungicides, herbicides). Develop integrated pest management approaches to offer alternative methods of pest control for producers	High	9. Pollution (Pesticides)	Ongoing
Promote conservation, maintenance, restoration and creation of native foraging habitat for the Yellow-banded Bumble Bee (i.e. flowers with short or open corollas, blooming through the active season), nesting habitat (underground burrows), and overwintering habitat (rotting logs, loose soil, mulch). Promote voluntary stewardship by landowners, government agencies, and holders of government reserves.	High	All threats to habitat	Ongoing
Restore/enhance habitat and mitigate stresses via mechanical actions (e.g., planting bee-friendly native flowering plants, etc.)	Medium	All threats to habitat	Ongoing
2. Species Management			
Manage introduced bumble bee and European Honey Bee populations to reduce transmission of pathogens and to reduce competition with Yellow-banded Bumble Bee	High	8. Pathogens	2023-2025 and ongoing
Ex-situ conservation: developing techniques for a captive rearing program (primarily for Rusty-patched Bumble Bee, using Yellow-banded Bumble Bee as a surrogate research species)	Low		2023-2032
3. Awareness Raising			
Raise awareness of Yellow-banded Bumble Bee (e.g., species' needs, occurrences, direct threats) with relevant government agencies (including indigenous organizations and governments), land owners and managers, farmers, beekeepers, and public via reported media, social media, advertisements and marketing, displays, person-to-person engagement, and workshops/experiential learning. Important to differentiate between the needs of native bumble bees and European Honey Bees.	High	All, Conservation capacity	Ongoing
6. Conservation Designation and Planning			
Plan for conserving and managing Yellow-banded Bumble Bee by completing recovery documents as appropriate	Medium	All threats	Ongoing

Promote habitat protection measures (such as conservation easements) to preserve and enhance bumble bee habitat. Consider native pollinators in local and regional land use planning.	Medium	All threats to habitat	Ongoing
Establish or demarcate protected areas; ensure that protected areas have pollinator management programs.	Low	All threats to habitat	Ongoing
7. Legal and Policy Frameworks			
Create, amend, or influence environment-related federal/ provincial/ territorial/Indigenous/ and/or municipal laws and/or regulations, policies, and/or guidelines/best practices to benefit Yellow-banded Bumble Bee (e.g. regarding transport and housing of bumble bees, disease testing of bumble bees, European Honey Bees, and other managed pollinators, pesticide regulations, slowing climate change, pollution, agricultural and forest land management, etc.)	High	All	2023-2027
8. Research and Monitoring			
Undertake extensive inventories throughout historical range (and areas immediately north of known range) to establish present range	High	Knowledge Gaps	2023-2032
Develop protocols and implement intensive, repeatable monitoring at throughout range; deposit specimens and data in central repositories (e.g. regional and national collections, and Conservation Data Centres)	High	Knowledge Gaps	Ongoing
Clarify identification issues with Western Bumble Bee and address any identification errors in collections	High	Knowledge Gaps	2023-2025
Continuing research into the effects of pesticides (insecticides, herbicides, and fungicides) on this species.	High	Knowledge Gaps 9. Pollution (Pesticides)	2023-2027, ongoing
Research into the effects of pathogens (e.g. *Varimorpha bombi*), and pathogen spillover from managed bees (*Bombus* in greenhouses, European Honey Bees, etc.)	High	Knowledge Gaps 8. Invasive and other problematic species	Ongoing
Research into competition with managed European Honey Bee colonies and feral European Honey Bee populations.	High	Knowledge Gaps 8. Invasive and other problematic species	Ongoing
Research into the effects of climate change (shifting climate envelopes, temperature extremes, droughts)	High	Knowledge Gaps 11. Climate Change	Ongoing
Research into effective population sizes, demographics, life history and other basic population ecology work	Medium	Knowledge Gaps	Ongoing
Ongoing research into developing captive rearing techniques	Low	Knowledge Gaps	Ongoing
9. Education and Training			
Provide conservation capacity development within government, First Nations, NGO, and agricultural sector, as well as volunteers, through hands-on coaching & technical assistance and developing training materials (e.g., bee identification, monitoring protocols)	High	Conservation Capacity	Ongoing

10. Institutional Development			
Create and maintain collaborations and partnerships focused on coordinating conservation implementation, knowledge generation & sharing	Medium	Conservation Capacity	Ongoing

[e] *"Priority" reflects the degree to which the measure contributes directly to the conservation of the species or is an essential precursor to a measure that contributes to the conservation of the species. High priority measures are considered those most likely to have an immediate and/or direct influence on attaining the management objective for the species. Medium priority measures may have a less immediate or less direct influence on reaching the management objective, but are still important for the management of the population. Low priority conservation measures will likely have an indirect or gradual influence on reaching the management objective, but are considered important contributions to the knowledge base and/or public involvement and acceptance of the species.*

6.4. Narrative to Support Conservation Measures and Implementation Schedule

6.4.1. High Priority: Essential

Pathogens and pathogen spillover from managed bumble bee colonies are widely believed to be central threats to the Yellow-banded Bumble Bee, so the control of these pathogens and their carriers may be key to the conservation of this species. More regulation and oversight of the managed European Honey Bee and bumble bee industry is needed. It is important to know how many managed bees are being moved, and where they are being moved to. There should be regular testing for diseases within production facilities, and protocols to minimize disease spread to the wild (e.g. greenhouse vent covers, freezing of colonies before disposal, etc.). The “Bumblebee Sector Guide” to the National Bee Farm-level Biosecurity Standard (Canadian Food Inspection Agency 2013) should be updated and followed. Because it is impossible to prevent all escapes from greenhouses, there should be no shipment of managed bumble bees outside their natural ranges.

However, these organisms and their effects on these bumble bees are not well known. Important research questions include: What is the geographic origin of these pathogens; i.e. are they exotic or native? How are they transferred from bee to bee? Why is the prevalence of *Varimorpha* related to the concentration of fungicides in the environment?

There is now considerable evidence showing that neonicotinoid and other insecticides have serious sub-lethal effects on bumble bees (see 4.2 Description of Threats). Reduction and control of insecticide use through regulations and best practices is vital to the conservation and recovery of bumble bee populations in agricultural areas. Continuing development of integrated pest management methods to offer growers alternatives to pesticides is a key part of this strategy (Labrie *et al.* 2020). The widespread use of herbicides in both agriculture and silviculture has undoubtedly greatly reduced the floral resources needed by bumble bees; best practices need to be followed to minimize the destruction of bee forage. Particular attention needs to be paid to drift of herbicides beyond the crop boundaries (even by a few metres) during mechanical or aerial spraying.

Continued pesticide research is essential to the conservation and recovery of this and other bumble bee species, especially research into the sub-lethal effects of insecticides (including the relatively new insecticides that are being developed to replace neonicotinoids), documentation of the effects of herbicides on pollinator forage resources, and the link between fungicides and bumble bee pathogens.

The issue of potential competition with European Honey Bee apiaries needs to be studied and, if deemed necessary, appropriate limits placed on European Honey Bee densities in Yellow-banded Bumble Bee habitat.

Widespread inventory is needed to establish the true extent of the functional range of the Yellow-banded Bumble Bee (and other bumble bees) in Canada. This is true both in the southern areas in which it has declined, and in the more remote areas where it may still thrive, but inventory data are lacking. Inventories should be done late in the season (mid-August for southern regions, late July for northern regions) in order to maximize the probability of encountering bumble bees. Continued identification and confirmation of specimens in research collections and regional museums is needed to fully understand the historical and present range.

Additional study on effective population sizes, demographics, life history and other basic population ecology work is required for the Yellow-banded Bumble Bee (e.g., Liczner and Colla 2019).

More intensive monitoring is needed to document ongoing trends. Monitoring in this plan means repeatable surveys at the appropriate time of year (see above) designed to measure an index of absolute abundance. These surveys would not only greatly enhance the re-assessment of the species, but they are also the only way of measuring progress in conservation efforts. Examples of monitoring include standardized roadside netting surveys, blue vane trap surveys, and pan trap surveys. Each method has its advantages and disadvantages; the key feature is that they can be repeated year after year and the results can be compared directly among years. It would be ideal if one survey type would be used across Canada, so that results could be summarized and compared nation-wide. Data and specimens from the surveys should be kept in central repositories (for example, data in provincial/territorial Conservation Data Centres, and specimens in recognized research collections).

Successful monitoring is dependent on investments in the training of paid and volunteer biologists and naturalists; including training in monitoring protocols, bumble bee identification, specimen preparation, and database entry. Training could occur within government, First Nations, the agricultural sector, and non-government organizations. Because monitoring necessarily involves specimen capture, investments also must be made in regional natural history collections in order to safely store specimens collected. Monitoring of bumble bees could be done within the context of a broader plan to monitor all bees, or even all pollinators.

Public education about the threats to bees and the enhancement of habitat for bees will support the broader conservation and recovery of bees in a number of ways. Raising awareness with relevant government agencies (including Indigenous governments, organizations and co-management boards), greenhouse operators, beekeepers, land owners and managers is also essential. The engagement of interested people through citizen science programs such as Bumble Bee Watch (Bumble Bee Watch 2019) and iNaturalist (iNaturalist 2020) will help monitor and map bumble bees while conservation and recovery efforts take place.

The intensification of agriculture and general ‘tidying’ of the landscape in deve loped regions has resulted in a loss of bee habitat. Existing foraging, nesting and overwintering habitat for bumble bees needs to be maintained and enhanced if they are to return to viable numbers in more developed regions. Programs that promote voluntary stewardship of pollinators would be valuable in this regard.

6.4.2. Medium Priority: Necessary

In areas of extensive private land, conservation easements could be a key strategy in the enhancement of habitat. Many other habitat conservation options are available on public and private lands, including land use planning.

In areas where habitat for bumble bees has been degraded by development (whether by residential, commercial, agricultural or transportation development), restoration and ongoing maintenance using bee-friendly native vegetation will increase local populations of all bumble bees, including Yellow-banded Bumble Bees.

For this wide-ranging species with complex needs, partnerships focused on coordinating conservation implementation, knowledge generation and sharing will be necessary in conservation efforts. Indigenous governments and organizations such as Indigenous environment committees should be engaged to contribute local and Traditional Knowledge. Workshops on the habitat needs of bees and how the public can assist will not only help habitat restoration but raise general awareness of the bees and their needs as well.

6.4.3. Low Priority: Beneficial

In areas that are dominated by private land, small protected areas could be useful (on a local scale) to help augment bumble bee populations. Protected areas in general should have pollinator management plans that may help establish populations in areas that otherwise have limited habitat available.

7. Measuring Progress

The performance indicators presented below provide a way to measure progress towards achieving the management objectives and monitoring the implementation of the management plan.

- In southern Canada (i.e., south of the boreal forest), declines have ceased and there is an observed or estimated increase in the abundance of the Yellow-banded Bumble Bee
- In the northern parts of its Canadian range (i.e. the boreal and taiga regions), there is no observed or estimated reduction in the abundance of the Yellow-banded Bumble Bee
- The geographic range (extent of occurrence) of the Yellow-banded Bumble Bee is maintained.

8. References

Abramson, C.I., J. Squire, A. Sheridan, and P.G. Mulder, Jr. 2004. The effect of insecticides considered harmless to honey bees (*Apis mellifera*): proboscis conditioning studies by using the insect growth regulators tebufenozide and diflubenzuron. Environmental Entomology 33: 378-388. https://doi.org/10.1603/0046-225X-33.2.378

Alger, S.A., P.A. Burnham, H.F. Boncristiani, and A.K. Brody. 2019. RNA virus spillover from managed honeybees (*Apis mellifera*) to wild bumblebees (*Bombus* spp.). PLoS ONE 14(6):e0217822. https://doi.org/10.1371/journal. pone.0217822

Arbetman, M.P., G. Gleiser, C.L. Morales, P. Williams, and M.A. Aizen. 2017. Global decline of bumblebees is phylogenetically structured and inversely related to species range size and pathogen incidence. Proceedings of the Royal Society B 284: 20170204. http://dx.doi.org/10.1098/rspb.2017.0204.

Arce, A.N., T.I. David, E.L. Randall, A. Ramos Rodrigues, T.J. Colgan, Y. Wurm, and R.J. Gill. 2017. Impact of controlled neonicotinoid exposure on bumblebees in a realistic field setting. Journal of Applied Ecology 54:1199-1208. doi: 10.1111/1365-2664.12792.

Balbuena, M.S., L. Tison, M.-L. Hahn, U. Greggers, R. Menzel, and W.M. Farina. 2015. Effects of sublethal doses of glyphosate on honeybee navigation. Journal of Experimental Biology 218:2799-2805. doi: 10.1242/jeb.117291.

Benbrook, C.M. 2016. Trends in glyphosate herbicide use in the United States and globally. Environmental Sciences 28:3. 15 pages. https://doi.org/10.1186/s12302-016-0070-0

Bernauer, O.M., H.R. Gaines-Day, and S.A. Steffan. 2015. Colonies of bumble bees (*Bombus impatiens*) produce fewer workers, less bee biomass, and have smaller mother queens following fungicide exposure. Insects 6:478-488. Doi:10.3390/insects6020478.

Brouillet, L., F. Coursol, S.J. Meades, M. Favreau, M. Anions, P. Bélisle, and P. Desmet. 2020. VASCAN, the Database of Vascular Plants of Canada. http://data.canadensys.net/vascan/ . Accessed 7 October 2020.

Brown, M. 2017. Microsporidia: an emerging threat to bumblebees? Trends in Parasitology 33:754-762. https://doi.org/10.1016/j.pt.2017.06.001

Brown, M.J.F., R. Loosli and P. Schmid-Hempel. 2000. Condition-dependent expression of virulence in a trypanosome infecting bumble bees. Oikos 91: 421–427.

Brown, M.J.F., R. Schmid-Hempel and P. Schmid-Hempel. 2003. Strong context-dependent virulence in a host-parasite system: reconciling genetic evidence with theory. Journal of Animal Ecology 72: 994–1002.

Bryden, J., R.J. Gill, R.A.A. Mitton, N.E. Raine, and V.A.A. Jansen. 2013. Chronic sublethal stress causes bee colony failure. Ecology Letters 16: 1463-1469. doi: 10.1111/ele.12188.

Bumble Bee Watch. 2019. Bumble Bee Watch website. Available at https://www.bumblebeewatch.org/. Accessed 12 December 2019.

Cameron, S.A., H.C. Lim, J.D. Lozier, M.A. Duennes, and R. Thorp. 2016. Test of the invasive pathogen hypothesis of bumble bee decline in North America. Proceedings of the National Academy of Sciences of the United States of America 113:4386-4391. doi: 10.1073/pnas.1525266113.

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

Canadian Association of Professional Apiculturalists. 2020. Statement on honey bee wintering losses in Canada (2020. Available at: https://capabees.com/shared/CAPA-Statement-on-Colony-Losses-2020.pdf

Canadian Biotechnology Action Network. 2018. 2,4-D- and Dicamba-tolerant crops. Available at: https://cban.ca/gmos/issues/pesticides/24-d-and-dicamba-tolerant-crops/. Accessed 30 October 2018.

Canadian Endangered Species Conservation Council. 2016. Wild Species 2015: The General Status of Species in Canada. National General Status Working Group: 128 pp. Available at: http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=3174. Accessed 2 August 2018.

Cane, J.H., and V.J. Tepedino. 2016. Gauging the effect of honey bee pollen collection on native bee communities. Conservation Letters https://doi.org/10.1111/conl.12263

Colla, S.R. 2017. Recovery Strategy for the Gypsy Cuckoo Bumble Bee (*Bombus bohemicus*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario. v + 23 pp.

Colla, S.R. and S. Dumesh. 2010. The bumble bees of southern Ontario: notes on natural history and distribution. Journal of the Entomological Society of Ontario 141:38-67.

Conservation Measures Partnership. 2016. Conservation Actions Classification (v2.0). Available at: https://cmp-openstandards.org/using-cs/tools/__actions/. Accessed 19 August 2020.

Corbet, S.A., M. Fussell, R. Ake, A. Fraser, C. Gunson, A. Savage, and K. Smith. 1993. Temperature and the pollinating activity of social bees. Ecological Entomology 18:17-30.

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.

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 Western Bumble Bee *Bombus occidentalis* (*occidentalis* subspecies – *Bombus occidentalis occidentalis* and *mckayi* subspecies – *Bombus occidentalis mckayi*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 52 pp.

COSEWIC. 2015. COSEWIC assessment and status report on the Yellow-banded Bumble Bee *Bombus terricola* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 60 pp.

Cox, C. 2001. Insecticide factsheet: Imidacloprid. Journal of Pesticide Reform 21:15-22.

Crall , J.D., C.M. Switzer, R.L. Oppenheimer , A.N. Ford Versypt, B. Dey, A. Brown, M. Eyster, C. Guérin , N.E. Pierce , S.A. Combes, and B.L. de Bivort. 2018. Neonicotinoid exposure disrupts bumblebee nest behavior, social networks, and thermoregulation. Science 362:683-686. doi: 10.1126/science.aat1598.

Czerwinski, M.A., and B. M. Sadd. 2017. Detrimental interactions of neonicotinoid pesticide exposure and bumblebee immunity. Journal of Experimental Zoology 327:273-283.

Droege, S. 2009. Bumblebee roadside surveys: results of a trial in Beltsville, MD U.S.A. and recommendations for further work. Available at: https://www.slideshare.net/sdroege/bumblebee-roadside-surveys-a-pilot-survey-and-recommendations. Accessed 2 August 2018.

Evans, E., R. Thorp, S. Jepson, and S.H. Black. 2008. Status review of three formerly common species of bumblebee in the subgenus *Bombus.* Report prepared for The Xerces Society for Invertebrate Conservation. 63 pages.

Feltham, H., K. Park, and D. Goulson. 2014. Field realistic doses of pesticide imidacloprid reduce bumblebee pollen foraging efficiency. Ecotoxicology 37:301–308.

ForestInfo. 2018. How much glyphosate is sprayed every year in forestry? ForestInfo website: http://forestinfo.ca/faqs/how-much-glyphosate-is-sprayed-every-year-in-forestry/. Accessed 28 September 2018.

Fürst, M.A., D.P. McMahon, J.L. Osborne, R.J. Paxton, and M.J.F. Brown. 2014. Disease associations between honeybees and bumblebees as a threat to wild pollinators. Nature 506:364-366.

Galbraith, S.M., J.H. Cane, A.R. Moldenke, J.W. Rivers. 2019. Wild bee diversity increases with local fire severity in a fire-prone landscape. Ecosphere 10: April 2019. https://doi.org/10.1002/ecs2.2668

Genersch, E., C. Yue, I. Fries, and J.R. de Miranda. 2005. Detection of *Deformed wing virus*, a honey bee viral pathogen, in bumble bees (*Bombus terrestris* and *Bombus pascuorum*) with wing deformities. Journal of Invertebrate Pathology 91: 61-63.
Gill, R.J., and N.E. Raine. 2014. Chronic impairment of bumblebee natural foraging behaviour induced by sublethal pesticide exposure. Functional Ecology 28:1459-1471. https://doi.org/10.1111/1365-2435.12292

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 Science19:10; 1–10. doi: 10.1093/jisesa/iez017

Giroux, I. 2019. Présence de pesticides dans l’eau au Québec : Portrait et tendances dans les zones de maïs et de soya – 2015 à 2017. Québec, ministère de l’Environnement et de la Lutte contre les changements climatiques, Direction générale du suivi de l’état de l’environnement, 64 p. + 6 ann.

Goblirsch, M. 2018. *Nosema ceranae* disease of the honey bee (*Apis mellifera*). Apidologie 49: 131-150. http://doi.org/10.1007/s3592-017-0535-1

Government of Northwest Territories. 2020. NWT Species Infobase. Available at: https://www.enr.gov.nt.ca/en/services/biodiversity/nwt-species-infobase. Accessed 4 March 2021.

Goulson, D. 2010. Bumblebees: behaviour, ecology, and conservation. Oxford Biology. 317 pages.

Graystock, P., D. Goulson, and W.O.H. Hughes. 2014. The relationship between managed bees and the prevalence of parasites in bumblebees. PeerJ2:e522. doi:10.771/peerj.522.

Graystock, P., K. Yates, B. Darvill, D. Goulson, and W.O. Hughes. 2013. Emerging dangers: deadly effects of an emergent parasite in a new pollinator host. Journal of Invertebrate Pathology 114:114-119. https://doi.org/10.1016/j.jip.2013.06.005

Graystock P.,E.J. Blane, Q.S. McFrederick, D. Goulson, and W.O.H. Hughes. 2016. Do managed bees drive parasite spread and emergence in wild bees? International Journal for Parasitology: Parasites and Wildlife 5:64-75. https://doi.org/10.1016/j.ijppaw.2015.10.001

Hatfield, R., S. Jepsen, R. Thorp, L. Richardson, and S. Colla. 2015. *Bombus terricola*. The IUCN Red List of Threatened Species 2015: e.T44937505A46440206. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T44937505A46440206.en. Downloaded on 15 February 2019.

Health Canada. 2016. Proposed Registration Decision PRD2016-08, Chlorantraniliprole. https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/consultations/proposed-registration-decisions/2016/chlorantraniliprole/document.html

Health Canada. 2017. Update on the neonicotinoid pesticides. Available at: https://www.canada.ca/content/dam/hc-sc/documents/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/update-neonicotinoid-pesticides/update-neonicotinoids-eng.pdf. Accessed 2 August 2018.

Health Canada. 2018. Proposed Re-evaluation Decision PRVD2018-12, Imidacloprid and its Associated End-use Products: Pollinator Re-evaluation. Available at: https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/consultations/proposed-re-evaluation-decisions/2018/imidacloprid/document.html. Accessed 29 August 2018.

Health Canada. Health Canada. 2019a. Thiamethoxam and its associated end-use products: pollinator re-evaluation. Final decision. Re-evaulation Decision RVD2019-04. Health Canada Pest Management Regulatory Agency, Ottawa, ON. 243 pages.

Health Canada. 2019b. Imidacloprid and its associated end-use products: pollinator re-evaluation. Final decision. Re-evaulation Decision RVD2019-06. Health Canada Pest Management Regulatory Agency, Ottawa, ON. 95 pages.

Health Canada. 2019c. Imidacloprid and its associated end-use products: pollinator re-evaluation. Final decision. Re-evaulation Decision RVD2019-06. Health Canada Pest Management Regulatory Agency, Ottawa, ON. 95 pages.

Health Canada 2020. Update on the neonicotinoid pesticides (January 2020). Available at: https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/update-neonicotinoid-pesticides-january-2020.html. Accessed 26 August 2020.

Health Canada. 2021a. Special Review Decision SRD2021-03: Clothianidin risk to aquatic invertebrates. Final Decision Document. Health Canada Pest Management Regulatory Agency, Ottawa, ON. 201 pages.

Health Canada. 2021b. Special Review Decision SRD2021-04: Thiamethoxam risk to aquatic invertebrates. Final Decision Document. Health Canada Pest Management Regulatory Agency, Ottawa, ON. 195 pages.

Health Canada. 2021c. Imidacloprid and its associated end-use products. Re-evaluation Decision RVD2021-05. Final Decision Document. Health Canada Pest Management Regulatory Agency, Ottawa, ON. 309 pages.

Hedrick, P.W., J. Gadau, and R.E. Page, Jr. 2006. Genetic sex determination and extinction. Trends in Ecology and Evolution 21:55-57. https://doi.org/10.1016/j.tree.2005.11.014

Helmer, S.H., A. Kerbaol, P. Aras, C. Jumarie, and M. Boily. 2014. Effects of realistic doses of atrazine, metolachlor, and glyphosate on lipid peroxidation and diet-derived antioxidants in caged honey bees (*Apis mellifera*). Environmental Science and Pollution Research. doi: 10.1007/s11356-014-2879-7. 14 pages.

Henry, M., and G. Rodet. 2018. Controlling the impact of the managed honeybee on wild bees in protected areas. Scientific Reports 8: 9308. https://www.nature.com/articles/s41598-018-27591-y

Herbert, L.T., D.E. Vázquez, A. Arenas, and W.M. Farina. 2014. Effects of field-realistic doses of glyphosate on honeybee appetitive behaviour. Journal of Experimental Biology 217:3457-3464. doi: 10.1242/jeb.109520.

iNaturalist. 2020. iNaturalist website. Available at https://inaturalist.ca/. Accessed 31 August 2020.

Javorek, S.K. and M.C. Grant. 2011. Trends in wildlife habitat capacity on agricultural land in Canada, 1986 – 2006. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 14. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 46 p. Available at: http://www.biodivcanada.ca/default.asp?lang=En&n=B6A77C14-1. Accessed 2 August 2018.

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 pages.

Johansen, C.A., and D.F. Mayer. 1990. Pollinator protection. A bee and pesticide handbook. Cheshire, CT. Wicwas Press.

Kosior, A., W. Celary, P. Olejniczak, J. Fijal, W. Krol, W. Solarz, and P.Plonka. 2007. The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of Western and Central Europe. Oryx 41:79-88.

Kent, C.F., A. Dey, H. Patel, N. Tsvetkov, T. Tiwari, V.J. McPhail, Y. Gobeil, B.A. Harpur, J. Gurtowski, M.C. Schatz, S.R. Colla, and A. Zayed. 2018. Conservation genomics of the declining North American bumblebee *Bombus terricola* reveals inbreeding and selection on immune genes. Frontiers in Genetics 9:316. doi: 10.3389/fgene.2018.00316.

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: 177-180. DOI: 10.1126/science.aaa7031.

Kraus, F.B., S. Wolf, and R.F.A. Moritz. 2008. Male flight distance and population substructure in the bumblebee *Bombus terrestris*. Journal of Animal Ecology 78:247-252. https://doi.org/10.1111/j.1365-2656.2008.01479.x

Labrie, G., A.-E. Gagnon, A. Vanasse, A. Latraverse, and G. Tremblay. 2020. Impacts of neonicotinoid seed treatments on soil-dwelling pest populations and agronomic parameters in corn and soybean in Quebe (Canada). PLoS ONE 15: e0229136. https://doi.org/10.1371/journal.pone.0229136.

Larsson, M. and M. Franzen. 2007. Critical resource levels of pollen for the declining bee *Andrena hattorfiana* (Hymenoptera, Andrenidae). Biological Conservation 134:405-414.

Laverty, T.M., and L.D. Harder. 1988. The bumble bees of eastern Canada. Canadian Entomologist 120:965-987. DOI: https://doi.org/10.4039/Ent120965-11

Lepais, O., B. Darvill, S. O'Connor, J.L. Osborne, R.A. Sanderson, J. Cussans, L. Goffe, and D. Goulson. 2010. Estimation of bumblebee queen dispersal distances using sibship reconstruction method. Molecular Ecology 19: 819-831.

Liczner, A., 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. https://doi.org/10.1007/s10841-019-00173-7

Liczner, A.R., and S.R. Colla. 2020. One size does not fit all: at-risk bumble bee habitat management requires species-specific local and landscape considerations. Insect Conservation and Diversity (2020). doi: 10.1111/icad.12419.

Macfarlane, R. 1974. Ecology of Bombinae (Hymenoptera: Apidae) of Southern Ontario, with emphasis on their natural enemies and relationships with flowers. PhD, University of Guelph, Guelph, Ontario.

Macfarlane, R.P., J.J. Lipa, and H.J. Liu. 1995. Bumble bee pathogens and internal enemies. Bee World 76: 130-148.

Mallinger, R.E., H.R. Gaines-Day, and C. Gratton. 2017. Do managed bees have negative effects on wild bees? A systematic review of the literature. PLoS ONE 12(12): e0189268 https://doi.org/10.1371/journal.pone.0189268.

Main, A.R., J.V. Headley, K.M. Peru, N.L. Michel, A.J. Cessna, and C.A. Morrissey. 2014. Widespread use and frequent detection of neonicotinoid insecticides in wetlands of Canada's Prairie pothole Region. PLoS ONE 9(3): e92821. https://doi.org/10.1371/journal.pone.0092821

Marletto, F., A. Patetta, and A. Manino. 2003. Laboratory assessment of pesticide toxicity to bumble bees. Bulletin of Insectology 56:155-158.

Master, L., D. Faber-Langendoen, R. Bittman, G.A. Hammerson, B. Heidel, J. Nichols, L. Ramsay and A. Tomaino. 2009. NatureServe Conservation Status Assessments: Factors for Assessing Extinction Risk. NatureServe, Arlington, VA.

McArt, S.H., C. Urbanowicz, S. McCoshum, R.E. Irwin, and L.S. Adler. 2017. Landscape predictors of pathogen prevalence and range contractions in US bumblebees. Proceedings of the Royal Society 9 B 284: 2017218. Available at: http://dx.doi.org/10.1098/rspb.2017.2181.

McFarland, K.P., L. Richardson, and S. Zahendra. 2015. Vermont Bumble Bee Survey: manual for participants. Available at: https://figshare.com/articles/Vermont_Bumble_Bee_Survey_-_Manual_for_Participants/6327230/1. Accessed 2 August 2018.

Meeus, I., M.J.F. Brown, D.C. De Graaf and G. Smagghe. 2011. Effects of invasive parasites on bumble bee declines. Conservation Biology 25:662-671.

Memmott, J., N.M. Waser, and M.V. Price. 2004. Tolerance of pollination networks to species extinctions. Proceedings of the Royal Society B 271:2605-2611.

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. doi: 10.1038/srep24764.

Mommaerts, V., S. Reynders, J. Boulet, L. Besard, G. Sterk, and G. Smagghe. 2010 Risk assessment for side-effects of neonicotinoids against bumblebees with and without impairing foraging behavior. Ecotoxicology 19:207–215.

Motta, E.V.S., K. Raymann, and N.A. Moran. 2018. Glyphosate perturbs the gut microbiota of honey bees. Proceedings of the National Academy of Sciences 115:10305-10310. Available at: https://doi.org/10.1073/pnas.1803880115. Accessed 25 September 2018.

National Forestry Database. 2019. National Forestry Database website. Available at: http://nfdp.ccfm.org/en/index.php. Accessed 4 October 2019.

National Research Council (NRC). 2007. Status of pollinators in North America. Committee on the Status of Pollinators in North America, The National Academies Press, Washington, D.C. 312 pp.

NatureServe. 2020. NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. Available at https://explorer.natureserve.org/. Accessed: 12 December 2020.

Northwest Territories Species at Risk Committee. 2019. Species status report for Western Bumble Bee, Yellow-banded Bumble Bee, and Gypsy Cuckoo Bumble Bee (*Bombus occidentalis, Bombus terricola, Bombus bohemicus*) in the Northwest Territories. Species at Risk Committee, Yellowknife, NT. 118 pages. Available at: https://www.nwtspeciesatrisk.ca/SARC/completed-assessment. Accessed 27 February 2020.

Nova Scotia Endangered Species Act - N.S. Reg. 2017. Categorized List of Species at Risk made under Section 12 of the Endangered Species Act S.N.S. 1998, c. 11 N.S. Reg. 146/2017. Available: https://www.novascotia.ca/just/regulations/regs/eslist.htm [accessed February 2019].

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. DOI: 10.1111/ele.12854.

Ontario Ministry of Agriculture, Food and Rural Affairs. 2019. Varroa mite: biology and diagnosis. Available at: http://www.omafra.gov.on.ca/english/food/inspection/bees/varroa-biology.htm. Accessed 8 October 2019.

Ontario Ministry of Environment, Conservation and Parks. 2018. Corn and soybean neonicotinoid-treated seed data. Ontario Data Catalogue. Available at:

https://data.ontario.ca/dataset/corn-and-soybean-neonicotinoid-treated-seed-data. Last Updated: February 2, 2018. Accessed 3 February 2020.

Ontario Ministry of the Environment, Conservation and Parks. 2019. Pollinator health. Available at: https://www.ontario.ca/page/pollinator-health. Accessed 16 September 2019.

Ontario Natural Heritage Information Centre. 2018. Website available at: https://www.ontario.ca/page/natural-heritage-information-centre. Accessed 16 September 2019.

Otterstatter, M.C., and J.D. Thomson. 2008. Does pathogen spillover from commercially reared bumble bees threaten wild pollinators? PLoS One 3: e2771.

Otti, O., and P. Schmid-Hempel. 2007. *Nosema bombi*: a pollinator parasite with detrimental fitness effects. Journal of Invertebrate Pathology. 96:118-124. https://doi.org/10.1016/j.jip.2007.03.016

Otti, O., and P. Schmid-Hempel. 2008. A field experiment on the effect of *Nosema bombi* in colonies of the bumblebee *Bombus terrestris*. Ecological Entomology. 33:577-582. https//doi.org/10.1111/j.1365-2311.2008.00998

Owen, E.L., J.S. Bale, and S.A.L. Hayward. 2013. Can winter-active bumblebees survive the cold? Assessing the cold tolerance of *Bombus terrestris audax* and the effects of pollen feeding. PLoS ONE 8: e80061. doi:10.1371/journal.pone.0080061.

Owen, R.E. and T.L. Whidden. 2013. Discrimination of the bumble bee species *Bombus occidentalis* Greene and *B. terricola* Kirby by morphometric, colour and RAPD variation. Zootaxa 3608: 328–344.

Palmier, K. and C. S. Sheffield. 2019. First records of the Common Eastern Bumble Bee, *Bombus impatiens* Cresson (Hymenoptera: Apidae, Apinae, Bombini) from the Prairies Ecozone in Canada. Biodiversity Data Journal 7: e30953. https://doi.org/10.3897/BDJ.7.e30953.

Peng, W.J., J.L. Li, H. Boncristiani, J.P. Strange, M. Hamilton and Y.P. Chen. 2011. Host range expansion of honey bee Black Queen Cell Virus in the bumble bee, *Bombus huntii.* Apidologie 42:650-658.

Pettis, J.S., E.M. Lichtenberg, M. Andree, J. Stitzinger, R. Rose, and D. vanEngelsdorp. 2013. Crop pollination exposes honey bees to pesticides which alters their susceptibility to the gut pathogen *Nosema ceranae*. PLoS ONE 8(7): e70182. doi:10.1371/journal.pone.0070182.

Pisa, L., V. Amaral-Rogers, L.P. Belzunces, J.-M. Bonmatin, C. Downs, D. Goulson, D. Kreutzweiser, C. Krupke, M. Liess, M. McField, C. Morrissey, D.A. Noome, J. Settele,

N. Simon-Delso, J. Stark, J.P. van der Sluijs, H. van Dyck, and M. Wiemers. 2014. Effects of neonicotinoids and fipronil on non-target invertebrates. Environmental Science and Pollution Research (2015) 22:68-102. doi:10.1007/s11356-014-3471-x.

Plath, O.E. 1934. Bumble bees and their ways. Macmillan, New York, US, 201 pp.

Plischuk, S., R. Martin-Hernandez, L. Prieto, M. Lucia, C. Botias, A. Meana, A.H. Abrahamovich, C. Lange and M. Higes. 2009. South American native bumble bees (Hymenoptera: Apidae) infected by *Nosema ceranae* (Microsporidia), an emerging pathogen of honey bees (*Apis mellifera*). Environmental Microbiology Reports 1:131-135.

Power, A.G., and C.E. Mitchell. 2004. Pathogen spillover in disease epidemics. American Naturalist 164:S79-S89.

Prescott, D., M. Wells, and L. Best. 2019. Survey of bumblebees in central Alberta - 2018. Alberta Environment and Parks - Species at Risk program. Occurrence dataset https://doi.org/10.5886/ntpd1n. Accessed via GBIF.org on 2020-10-21.

Raine, N. 2018. Pesticide affects social behavior of bees. Science 362:643-644. doi: 10.1126/science.aav5273.

Rasmont, P., and S. Iserbyt. 2012. The Bumblebees Scarcity Syndrome: are heat waves leading to local extinctions of bumblebees (Hymenoptera: Apidae: *Bombus*)? Annales Société Entomologique de France 48:275-280.

Rasmont, P., S. Roberts, B. Cederberg, V. Radchenko, and D. Michez. 2015a. *Bombus bohemicus*. The IUCN Red List of Threatened Species 2015. Available at: http://www.iucnredlist.org/details/13152926/1. Accessed on 2 August 2018.

Rasmont, P., M. Franzen, T. Lecocq, A. Harpke, S.P.M. Roberts, J.C. Biesmeijer, L. Castro, B. Cederberg, L. Dvořak, U. Fitzpatrick, Y. Gonseth, E. Haubruge, G. Mahe, A. Manino, D. Michez, J. Neumayer, F. Odegaard, J. Paukkunen, T. Pawlikowski, S.G. Potts, M. Reemer, J. Settele, J. Straka, and O. Schweiger. 2015b. Climatic risk and distribution atlas of European bumblebees. Biorisk 10 (Special Issue). 236 pages. Available at: https://biorisk.pensoft.net/articles.php?id=4749.

Richardson, L. 2019. Personal communication regarding Maine Bumble Bee Atlas data. University of Vermont. Email to S. Cannings 15 January 2019.

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.

Schlindwein, C., D. Wittmann, C.F. Martins, A. Hamm, J. Alves Siqueira, D. Schiffler, and I.C. Machado. 2005. Pollination of *Campanula rapunculus* L. (Campanulaceae): how much pollen flows into pollination and into reproduction of oligolectic pollinators? Plant Systematics and Evolution 250:147-156.

Seeley, T.D. 1995. The wisdom of the hive. Harvard Univ. Press, Cambridge, MA. 318 pages.

Sikes, D., and J.J. Rykken. 2020. Update to the identification guide to female Alaskan bumble bees and a summary of recent changes to the Alaskan bumble bee fauna. Alaska Entomological Society Newsletter 13(1):31-38. Available at http://www.akentsoc.org/newsletter.php. Accessed 20 August 2020. doi:10.7299/X7GH9J8D.

Sirois-Delisle, C. and J.T. Kerr. 2018. Climate change-driven range losses among bumblebee species are poised to accelerate. Scientific Reports 8, Article number: 14464. https://doi.org/10.1038/s41598-018-32665-y

Siviter, H., M.J.F. Brown, and E. Leadbeater. 2018. Sulfoxaflor exposure reduces bumblebee reproductive success. Nature 561:109-112.

Smagghe, G., J. Keknopper, I. Meeus, and V. Mommaerts. 2013. Dietary chlorantaniliprole suppresses reproduction in worker bumblebees. Pest Management Science 69:787-791. doi: 10.1002/ps.3504. Epub 2013 Apr 5.

Smagghe, G. S. Reynders, I. Maurissen, J. Boulet, X. Cuvelier, E. Dewulf, K. Put, C. Jans, G. Sterk, and V. Mommaerts. 2007. Analysis of side effects of diflubenzuron and tebufenozide in pollinating bumblebees *Bombus terrrestris*. Revue Synthèse 16:39-49. Available at: https://www.ajol.info/index.php/srst/article/view/117827. Accessed 4 January 2019.

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., K.E. Smith, and N.E. Raine. 2015a. Bumblebee learning and memory is impaired by chronic exposure to a neonicotinoid pesticide. Scientific Reports 5, article number: 16508. https://doi.org/10.1038/srep16508.

Stanley, D.A., M.P.D. Garratt, J.B. Wickens, V.J. Wickens, S.G. Potts, and N.E. Raine. 2015b. Neonicotinoid pesticide exposure impairs crop pollination services provided by bumblebees. Nature 528:548–550.

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. https://doi.org/10.1111/1365-2664.12689

Statistics Canada. 2017. 2016 census of agriculture. Available at: https://www150.statcan.gc.ca/n1/daily-quotidien/170510/dq170510a-eng.htm?indid=10441-2&indgeo=0. Accessed 28 September 2018.

Stout, J. and D. Goulson. 2000. Bumble bees in Tasmania: Their distribution and potential impact on Australian flora and fauna. Bee World 81:80-86. DOI: 10.1080/0005772X.2000.11099475

Straw, E.A., E.N. Carpentier, M.J.F. Brown. 2021. Roundup causes high levels of mortality following contact exposure in bumble bee. Journal of Applied Ecology 58:1167-1176. https://doi.org/10.1111/1365-2664.13867

Szabo, N., S.R. Colla, D.Wagner, L.F. Gall, and J.T. Kerr. 2012. Is pathogen spillover from commercial bumble bees responsible for North American wild bumble bee declines? Conservation Letters 5: 232-239.

Tasei, J.N., G. Ripault, and E. Rivault. 2001. Hazards of Imidacloprid seed coating to *Bombus terrestris* (Hymenoptera: Apidae) when applied to Sunflower. Journal of Economic Entomology 94:623-627.

Thompson, D.G., and D. Pitt. 2011. Frequently asked questions (FAQs) on the use of herbicides in Canadian forest. Frontline Technical Note 112. Canadian Forest Service, Great Lakes Forestry Centre, Ontario. Available at: http://www.cfs.nrcan.gc.ca/pubwarehouse/pdfs/32344.pdf.

Thorp R.W., and M.D. Shepherd. 2005. Profile: subgenus Bombus. In: Shepherd M.D., Vaughan D.M., Black S.H.(editors). Red list of pollinator insects of North America. The Xerces Society for Invertebrate Conservation, Portland, OR.

Tucker, E.M., and S.M. Rehan. 2017. High elevation refugia for *Bombus terricola* (Hymenoptera: Apidae) conservation and wild bees of the White Mountain National Forest. Journal of Insect Science 17:4; 1–10. doi: 10.1093/jisesa/iew093

van der Sluijs, J.P., V. Amaral-Rogers, L.P. Belzunces, M.F.I.J. Bijleveld van Lexmond, J.-M. Bonmatin, M. Chagnon, C. A. Downs, L. Furlan, D. W. Gibbons, C. Giorio, V. Girolami, D. Goulson, D.P. Kreutzweiser,C. Krupke,M. Liess, E. Long,M. McField, P. Mineau,E.A.D. Mitchell, C.A. Morrissey, D.A. Noome, L. Pisa, J. Settele, N. Simon-Delso, J.D. Stark, A. Tapparo, H. Van Dyck, J. van Praagh, P.R. Whitehorn, and M. Wiemers. 2014. Conclusions of the worldwide integrated assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning. Environmental Science and Pollution Research (2015) 22: 148–154. doi:10.1007/s11356-014-3229-5.

van der Steen, J.J.M. 2008. Infection and transmission of *Nosema bombi* in *Bombus terrestris* colonies and its effect on hibernation, mating and colony founding. Apidologie 39:273-282. https://hal.archives-ouvertes.fr/hal-00891960

Weidenmüller, A., A. Meltzer, S. Neupert, A. Schwarz, and C. Kleineidam. 2022. Glyphosate impairs collective thermoregulation in bumblebees. Science 376: 1122-1126. https://doi.org/10.1126/science.abf7482

Whitehorn, P.R., S. O'Connor, F.L. Wackers, and D. Goulson. 2012. Neonicotinoid pesticide reduces bumble bee colony growth and queen production. Science 336:351-352.

Wiemers. 2014. Conclusions of the worldwide integrated assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning. Environmental Science and Pollution Research (2015) 22: 148–154. doi:10.1007/s11356-014-3229-5.

Williams, P.H. 2018. *Bombus*: Species world-wide listed by old and new subgenera [Online]. Natural History Museum, London, UK. Available at: http://www.nhm.ac.uk/research-curation/research/projects/bombus/subgenericlist. Accessed August 1, 2018.

Williams, P.H., S.R. Colla and Z. Xie. 2009. Bumble bee vulnerability: common correlates of winners and losers across three continents. Conservation Biology 23:931-940.

Williams, P.H., and J.L. Osborne. 2009. Bumblebee vulnerability and conservation world-wide. Apidologie 40:367-387.

Williams, P.H., R.W. Thorp, L.L. Richardson, and S.R. Colla. 2014. The bumble bees of North America: an identification guide. Princeton University Press. NY, USA. 208 pages.

Winston, M.L. 1987. The biology of the honey bee. Harvard University Press, Cambridge, MA.

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.

Ziska, L.H., J.S. Pettis, J. Edwards, J.E. Hancock, M.B. Tomecek, A. Clark, J.S. Dukes, I. Loladze and H.W. Polley. 2016. Rising atmospheric CO2 is reducing the protein concentration of a floral pollen source essential for North American bees. Proceedings of the Royal Society B, 20160414. http://dx.doi.org/10.1098/rspb.2016.0414.

Personal Communications

Palmier, K. 2020. Personal communication. Email to S. Cannings on 2 February 2020.

Raine, N. 2019. Personal communication. Email to S. Cannings 10 June 2019.

Sheffield, C. 2018. Personal communication. Royal Saskatchewan Museum, Regina. Telephone conversation with S. Cannings.

Appendix A: Plant food sources for the Yellow-banded Bumble Bee

Bumble bees are generalist feeders; these are examples of flowers that Yellow-banded Bumble Bees have been recorded foraging on, given in, Macfarlane (1974), Colla and Dumesh (2010), and Williams *et al.* (2014). Some regions of the bee's range may be over-empasized in this list (e.g. southeastern Canada, northeastern United States); others may be under-represented (e.g. far northwest). English names compiled from Brouillet *et al.* (2020).

Anaphalis margaritacea	Pearly Everlasting
Aquilegia canadensis	Red Columbine
Aralia sp.	Sarsaparilla
Arctostaphylos uva-ursi	Common Bearberry
Asclepias incarnata	Swamp Milkweed
Asclepias syriaca	Common Milkweed
Astragalus sp.	Milk-vetches
Baptisia tinctoria	Yellow Wild Indigo
Berberis thunbergii	Japanese Barberry
Caragana arborescens	Siberian Pea Shrub
Carduus nutans	Nodding Thistle
Centaurea jacea	Brown Knapweed
Chamaenerion [=Epilobium] angustifolium	Fireweed
Cirsium arvense	Canada Thistle
Crocus sp.	Crocuses
Diervilla lonicera	Northern Bush-honeysuckle
Epigaea repens	Trailing Arbutus
Erigeron philadelphicus	Philadelphia Fleabane
Eupatorium fistulosum	Hollow Joe Pye Weed
Eupatorium maculatum	Spotted Joe Pye Weed
Eurybia macrophylla	Large-leaved Aster
Euthamia graminifolia	Grass-leaved Goldenrod
Echium vulgare	Common Viper's Bugloss
Gaylussacia sp.	Huckleberry
Heracleum lanatum	American Cow Parsnip
Hydrophyllum virginianum	Virginia Waterleaf
Hypericum perforatum	Common St. John's-wort
Impatiens capensis	Spotted Jewelweed
Kalmia augustifolia	Sheep Laurel
Lactuca Canadensis	Canada Lettuce
Rhododendron [=Ledum] groenlandicum	Common Labrador Tea
Linaria vulgaris	Butter-and-eggs
Lonicera caerulea	Blue Fly-honeysuckle
Lonicera tatarica	Tatarian Honeysuckle
Lupinus sp.	Lupines
Melilotus albus	White Sweet-clover
Medicago sativa	Alfalfa
Mertensia sp.	Bluebells
Monarda fistulosa	Wild Bergamot
Onopordum acanthium	Scotch Thistle
Philadelphus coronaries	European Mock-orange
Pontederia cordata	Pickerelweed
Prunus cerasus	Sour Cherry

Prunus pensylvanica	Pin Cherry
Prunus tomentosa	Nanking Cherry
Malus pumila [=Pyrus malus]	Common Apple
Rhexia virginica	Virginia Meadow Beauty
Rhus typhina	Staghorn Sumac
Ribes grossularia	European Gooseberry
Ribes nigrum	European Black Currant
Robinia hispida [=fertilis]	Bristly Locust
Rosa sp.	Roses
Rubus sp.	Brambles
Salix sp.	Willows
Senecio sp.	Groundsels
Solanum dulcamara	Bittersweet Nightshade
Solidago canadensis	Canada Goldenrod
Solidago flexicaulis	Zigzag Goldenrod
Solidago hispida	Hairy Goldenrod
Solidago juncea	Early Goldenrod
Sonchus oleraceus	Common Sow-thistle
Sorbus Americana	American Mountain-ash
Spiraea latifolia	Broad-leaved Meadowsweet
Symphyotrichum ericoides	White Heath Aster
Symphyotrichum lateriflorum	Calico Aster
Symphyotrichum novae-anglia	New England Aster
Symphytum officinale	Common Comfrey
Syringa vulgaris	Common Lilac
Taraxacum officinale	Common Dandelion
Thalictrum pubescens	Tall Meadow-rue
Tilia americana	Basswood
Tilia platyphyllos	Large-leaved Linden
Trifolium hybridum	Alsike Clover
Trifolium pretense	Red Clover
Trifolium repens	White Clover
Vaccinium angustifolium	Early Lowbush Blueberry
Vaccinium corymbosum	Highbush Blueberry
Vicia cracca	Tufted Vetch

Appendix B: Effects on the Environment and Other Species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*[5]. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or any of the Federal Sustainable Development Strategy's[6] (FSDS) goals and targets.

Conservation planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that implementation of management plans may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the management plan itself, but are also summarized below in this statement.

Conservation efforts for the Yellow-banded Bumble Bee are essential to the recovery of the Gypsy Cuckoo Bumble Bee and the Suckley's Cuckoo Bumble Bee. Additionally, they should benefit all bumble bees, as well as other insect pollinators such as the Monarch (*Danaus plexippus*). The approaches presented in Table 4 will likely benefit these other species by reducing bee pathogen transmission, as well as pesticide use.

Bumble bees in general, are important pollinators of many native flowering plants and crops (COSEWIC 2010, 2014, 2015). They have several characteristics that contribute to their effectiveness as pollinators of crop plant species (Corbet *et al.* 1993). For example, they are able to fly at lower temperatures than other bees, which allows for a longer work day and improves pollination of crops during inclement weather. They also have the capacity to "buzz pollinate," which can increase the rate of pollination of plants. Some cultivated plants, such as tomatoes, peppers, and blueberries, benefit from buzz pollination (Jepsen *et al.* 2013). Bumble bees are likely the primary pollinators for many ecologically and economically important plants, including apples, raspberries, cranberries, blueberries, and clovers. They are excellent pollinators of crops such as alfalfa and onion (COSEWIC 2010, 2014, 2015). They play a vital role as generalist pollinators of native flowering plants, and their decline or loss could have far-ranging impacts (Jepsen *et al*. 2013). It has been shown that the loss of bumble bees would cause a greater number of plant extinctions than would the loss of specialist pollinators (Memmott *et al.* 2004).

[5] www.canada.ca/en/environmental-assessment-agency/programs/strategic-environmental-assessment/cabinet-directive-environmental-assessment-policy-plan-program-proposals.html
[6] www.fsds-sfdd.ca/index.html#/en/goals/