COSEWIC
Assessment and Status Report

on the

Western Bumble Bee
Bombus occidentalis

occidentalis subspecies - *Bombus occidentalis occidentalis*
mckayi subspecies - *Bombus occidentalis mckayi*

in Canada

***occidentalis* subspecies - THREATENED**
***mckayi* subspecies - SPECIAL CONCERN**
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Western Bumble Bee — Cover photograph by David Inouye, Western Bumble Bee worker robbing an Ipomopsis flower.

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COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Western Bumble Bee - *occidentalis* subspecies

Scientific name
Bombus occidentalis occidentalis

Status
Threatened

Reason for designation
This bumble bee ranges in Canada from British Columbia (south of approximately 55-57ºN), through southern Alberta east to southern Saskatchewan. Approximately 30-40% of its global range is in Canada. Once considered one of the most common and widespread bumble bees in western Canada, this subspecies has experienced a significant (>30%) decline in recent years and has been lost from a number of sites in the southern portions of its range where it was once abundant. It has among the highest parasite loads (particularly the microsporidian *Nosema bombi*) of any bumble bee in North America. Ongoing threats to the species, particularly within the southern portions of its range, include pathogen spillover from commercially managed bumble bee colonies, increasingly intensive agricultural and other land use practices, pesticide use (including neonicotinoid compounds), and habitat change.

Occurrence
British Columbia, Alberta, Saskatchewan

Status history
Designated Threatened in May 2014.

Assessment Summary – May 2014

Common name
Western Bumble Bee - *mckayi* subspecies

Scientific name
Bombus occidentalis mckayi

Status
Special Concern

Reason for designation
This subspecies ranges in Canada from northern British Columbia (north of approximately 55-57ºN) through southern Yukon and westernmost Northwest Territories; at least 50% of its global range is in Canada. Recent surveys in northwestern Canada and Alaska suggest that it is still common. However, the southern subspecies of the Western Bumble Bee is experiencing a serious, apparently northward-moving decline, and because the causes of this decline are unknown, the northern subspecies faces an uncertain future. Recent studies in Alaska suggest that this subspecies has among the highest parasite loads (particularly the microsporidian *Nosema bombi*) of any bumble bee species in North America. Other potential threats include the unknown transmission of disease from exotic bumble bee species introduced for pollination in greenhouses (ongoing in the Yukon), pesticide use (including neonicotinoid compounds), and habitat change.

Occurrence
Yukon, Northwest Territories, British Columbia

Status history
Designated Special Concern in May 2014.

COSEWIC
Executive Summary

Western Bumble Bee
Bombus occidentalis

occidentalis subspecies - *Bombus occidentalis occidentalis*
mckayi subspecies - *Bombus occidentalis mckayi*

Wildlife Species Description and Significance

Western Bumble Bee, *Bombus occidentalis* Greene, is one of five North American members of the subgenus *Bombus sensu stricto*. It is a medium-sized (1 – 2 cm) bumble bee with a short head. The abdomen is colour variable, but all individuals have a transverse band of yellow hair on the thorax in front of the wing bases, and the tip of the abdomen is almost always white.

Bumble bee taxonomy is widely debated, including the taxonomic history of Western Bumble Bee. The species was once considered synonymous with Yellow-banded Bumble Bee; however, recent genetic work confirms these two species as separate. Additional recent taxonomic work further splits Western Bumble Bee into two separate subspecies: *Bombus occidentalis occidentalis* and *Bombus occidentalis mckayi*, based on genetic, morphological and distributional information.

Distribution

Western Bumble Bee ranges throughout most of western North America. Subspecies *occidentalis,* ranges from central California north to northern British Columbia, and east into southern Saskatchewan and South Dakota. Subspecies *mckayi* ranges from central-northern British Columbia northward into the Yukon, Northwest Territories and Alaska.

Habitat

Western Bumble Bee lives in a diverse range of habitats, including mixed woodlands, farmlands, urban areas, montane meadows and into the western edge of the prairie grasslands. Subspecies *mckayi* is seemingly restricted to the Boreal and Cordilleran Ecological Areas. Western Bumble Bee has been recorded gathering pollen and nectar from the flowers of a variety of plant genera. Like many bumble bees, it typically nests underground in abandoned rodent burrows or within hollows in decaying wood.

Biology

Western Bumble Bee has an annual life cycle. Mated queens (colony founders) emerge from wintering sites in the spring and search for potential nest sites. Once a nest site is chosen, the queen then forages for pollen and nectar, returning to the nest site to lay eggs which will eventually produce a brood of workers. Workers emerge and take over nest care, pollen and nectar foraging. In late summer, males and new queens are produced. These reproductive individuals leave the colony, mate, and only the mated queens enter hibernation while all other castes, including the old queen, perish at the onset of colder temperatures.

Population Sizes and Trends

Subspecies *occidentalis* continues to be recorded throughout most of its historical range in Canada, although at fewer sites and with lesser abundance: relative abundance data within the past ten years suggests a probable decline of more than 30%. In the regions in Canada where subspecies *occidentalis* has been most studied (i.e., southern BC and AB), significant declines in relative abundance have occurred at all surveyed sites within the last three decades. Subspecies *mckayi* is more commonly observed, and with a constant abundance, although there is little historical data for this subspecies from which to derive trends.

Threats and Limiting Factors

Possible threats to subspecies *occidentalis* may include the transfer of pathogens from managed bees used for greenhouse pollination that have escaped. Additional regional threats include agricultural pesticide and chemical use, and habitat loss.

Protection, Status, and Ranks

There is currently no legal protection in Canada for either subspecies of Western Bumble Bee. All members of subgenus *Bombus* appear to be globally declining.

TECHNICAL SUMMARY – DU1

Bombus occidentalis occidentalis

Western Bumble Bee *occidentalis* subspecies — Bourdon de l'Ouest de la sous-espèce *occidentalis*

Range of occurrence in Canada: BC, AB, SK

Demographic Information

Generation time	1 yr
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes. Observed and inferred continuing decline of > 30% based on lower relative abundance within the past ten years and null data at some sites where formerly common.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Observed, inferred and suspected continuing decline of > 30% based on lower relative abundance within the past ten years and null data at some sites where formerly common.
Are the causes of the decline clearly reversible and understood and ceased?	Not clearly reversible; partially understood; not ceased.
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	1,000,000 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	Unknown, wide-ranging species; >> 2000 km².
Is the total population severely fragmented?	No
Number of locations*	Unknown, wide-ranging species; >>10 locations.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unknown

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

Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Yes. Observed and inferred based on lower abundance during recent surveys and failure to detect species at some sites where once common.
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Yes. Observed and inferred based on lower abundance during recent surveys and failure to detect species at some sites where once common.
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Yes. Observed and inferred based on lower abundance during recent surveys and failure to detect species at some sites where once common.
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Yes. Observed and inferred continuing decline in habitat quality based on lower abundance during recent surveys and failure to detect species at some sites where once common.
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
subspecies *occidentalis*	Unknown
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not calculated

Threats (actual or imminent, to populations or habitats)

Subspecies *occidentalis* has among the highest parasite loads (particularly the microsporidian *Nosema bombi*) of any bumble bee in North America. Ongoing threats to the subspecies, particularly within the southern portions of its range, include pathogen spillover and the transmission of disease from exotic and commercially managed bumble bee colonies introduced for greenhouse pollination, pesticide use (including neonicotinoid compounds), and more intensive agricultural land use practices and overall habitat change in some parts of its range.

Rescue Effect (immigration from outside Canada)

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

Status of outside population(s)? Subspecies *occidentalis* ranges in the western United States where it has also substantially declined within this part of its range. Bumble bee dispersal is limited to the spring when solitary queens search for suitable nest sites. During this time, queens are likely using reserve energy for nest establishment and minimize energy spent on long-distance dispersal. Undocumented populations within unsurveyed suitable natural habitats may be able to disperse from adjacent WA, ID, MO, and ND into Canada.	
Is immigration known or possible?	Unknown but possible from the United States
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes, at least within natural habitats.
Is rescue from outside populations likely?	No. Populations in the United States have declined.

Status History

COSEWIC: Designated Threatened in May 2014

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** A2abce
Reasons for designation: This bumble bee ranges in Canada from British Columbia (south of approximately 55-57ºN), through southern Alberta east to southern Saskatchewan. Approximately 30-40% of its global range is in Canada. Once considered one of the most common and widespread bumble bees in western Canada, this subspecies has experienced a significant (>30%) decline in recent years and has been lost from a number of sites in the southern portions of its range where it was once abundant. It has among the highest parasite loads (particularly the microsporidian *Nosema bombi*) of any bumble bee in North America. Ongoing threats to the species, particularly within the southern portions of its range, include pathogen spillover from commercially managed bumble bee colonies, increasingly intensive agricultural and other land use practices, pesticide use (including neonicotinoid compounds), and habitat change.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Threatened A2bce with a suspected decline of greater than 30% based on a much larger decline in relative abundance in survey samples, as well as recent, continuous, and more intensive agricultural habitat conversion, and high pathogen loads in the southern parts of its range.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EO exceeds thresholds and the IAO is unknown.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. The population size is unknown.
Criterion D (Very Small or Restricted Total Population): Not applicable. EO is too large and the population size is unknown.
Criterion E (Quantitative Analysis): None completed.

TECHNICAL SUMMARY – DU2

Bombus occidentalis mckayi

Western Bumble Bee *mckayi* subspecies — Bourdon de l'Ouest de la sous-espèce *mckayi*

Range of occurrence in Canada:northern BC, YT, western NT

Demographic Information

Generation time	1 year
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No. Collected during recent (2009 – 2013) surveys in northern BC and YT
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Not applicable
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	ca 400,000 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	Unknown
Is the total population severely fragmented?	No
Number of locations*	Unknown, wide-ranging; >>10 locations
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No

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

Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
subspecies *mckayi*	Unknown
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not calculated.

Threats (actual or imminent, to populations or habitats)

Recent studies in Alaska suggest that this subspecies has among the highest parasite loads (particularly the microsporidian *Nosema bombi*) of any bumble bee species in North America. Other potential threats include the unknown transmission of disease from exotic bumble bee species introduced for pollination in greenhouses (ongoing in the Yukon), pesticide use (including neonicotinoid compounds), and habitat change.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Subspecies *mckayi* appears common throughout most of its range in northern BC, YK and NT. Rescue effect from Alaska is possible.	
Is immigration known or possible?	Possible. Specimens are recorded in AK.
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes. Habitat is continuous between Canada and AK.
Is rescue from outside populations likely?	Yes

Status History

COSEWIC: Designated Special Concern in May 2014.

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not applicable.

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

Reasons for designation:
This subspecies ranges in Canada from northern British Columbia (north of approximately 55-57ºN) through southern Yukon and westernmost Northwest Territories; at least 50% of its global range is in Canada. Recent surveys in northwestern Canada and Alaska suggest that it is still common. However, the southern subspecies of the Western Bumble Bee is experiencing a serious, apparently northward-moving decline, and because the causes of this decline are unknown, the northern subspecies faces an uncertain future. Recent studies in Alaska suggest that this subspecies has among the highest parasite loads (particularly the microsporidian *Nosema bombi*) of any bumble bee species in North America. Other potential threats include the unknown transmission of disease from exotic bumble bee species introduced for pollination in greenhouses (ongoing in the Yukon), pesticide use (including neonicotinoid compounds), and habitat change.

Applicability of Criteria

Criterion A: Not applicable. This subspecies is not known to be declining at present. Data are not available to document declines.
Criterion B: Not applicable because the EO (>500,000 km²) exceeds the threshold, the IAO is not known, and there are more than 10 locations.
Criterion C: Not applicable. The population size is unknown.
Criterion D: Not applicable. The population size is unknown.
Criterion E: None completed.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2014)

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

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

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

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

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

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

COSEWIC Status Report

on the

Western Bumble Bee
Bombus occidentalis

occidentalis subspecies - *Bombus occidentalis occidentalis*
mckayi subspecies - *Bombus occidentalis mckayi*

in Canada

2014

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Phylum Arthropoda – arthropods

Class Insecta – insects

Subclass Pterygota – winged insects

Order Hymenoptera – sawflies, ants, bees, wasps

Suborder Apocrita – narrow-waisted wasps

Infraorder Aculeata – stinging wasps

Superfamily Apoidea – sphecoid wasps and apoid wasps (bees)

Family Apidae – includes among others, the bumble bees, euglossine(s), honey bees, stingless bees

Subfamily Apinae

Genus *Bombus* Latreille – bumble bees

Subgenus *Bombus* Latreille *sensu stricto*

Species *B. occidentalis* Greene

Subspecies *B. o. occidentalis* Greene and *B. o. mckayi* Ashmead

French common name: Bourdon de l'Ouest

English common name: Western Bumble Bee

The genus *Bombus* includes approximately 250 species found primarily in temperate regions of North America, Central America, South America, Europe and Asia. Western Bumble Bee (*Bombus occidentalis*) belongs to the subgenus *Bombus sensu stricto*, one of 15 subgenera of bumble bees recognized globally. In North America, subgenus *Bombus* contains four additional species: *Bombus affinis* Cresson, *B. cryptarum* (Fabricius), *B. franklini* Frison, and *B. terricola* Kirby.

Bumble bees are primarily identified using colour patterns at the adult life stage, although in many species colour patterns are variable. This variation has contributed to historical and recent taxonomic difficulties with many bumble bee species, including Western Bumble Bee.

Bombus occidentalis was first described as a distinct species by Greene (1858), and subsequently recognized as conspecific with *B. terricola* at the species' level (e.g., Milliron 1971; Cameron *et al.* 2007 [though Milliron considered it a distinct subspecies]), and by other authors as a distinct species (e.g., Stephen 1957; Thorp *et al.* 1983).

Cameron *et al.* (2007) recently compared DNA sequences from the 16S mitochondrial gene and found the two taxa (i.e., *B. occidentalis* and *B. terricola*) to be conspecific. However, Williams *et al.* (2012) reported that mitochondrial cytochrome c oxidase (COI) gene sequences (i.e., DNA barcodes) were sufficiently different to consider *B. occidentalis* a distinct species. These results support those of Bertsch *et al.* (2010), with an overall COI sequence divergence of approximately 5% between the two species. Furthermore, Owen and Whidden (2013) found consistent morphological and molecular characters supporting two distinct taxa. Thus, *B. occidentalis* is considered distinct and separate from *B. terricola*.

Williams *et al.* (2012) also found divergence in COI sequences within samples of Western Bumble Bee correlated with geography and recognized two subspecies: *B. o. occidentalis* and *B. o. mckayi*. For further information on the molecular phylogeny by Williams *et al.* (2012) which verified the division of Western Bumble Bee into two distinct genotypes. Current research based on molecular, morphological, and distributional data supports this conclusion (Sheffield *et al.* 2013). In recognition of this, *B. occidentalis* is presented in this status report as two subspecies: subspecies *occidentalis* and subspecies *mckayi*.

Morphological Description

Bumble bees are holometabolous insects. They have four developmental stages (e.g., egg, larvae, pupae, and adult) and are primitively eusocial with three adult forms or castes: the queen (reproductive female), female workers (non-reproductive) and males. Western Bumble Bee adults are highly colour variable, primarily on the scutellum (the hard plate on the dorsal side of the bumble bee thorax, usually where the wings attach), and on the second and third abdominal segments, which can range from black to yellow (details below).

Females: Queens and workers show a similar range in colour patterns, although they differ in size (queen length 1.6-1.9 cm, worker length 1.1-1.3 cm). The head is entirely black (Figure 1) and the malar space (i.e. area between the lower edge of the compound eye and the base of the mandible) is short (i.e. approximately as long as broad). All individuals have a transverse band of yellow hair anterior to the wing bases. Abdominal colouration is variable, ranging from all black on the first four segments (Figure 1) to individuals having the third (and sometimes part of the second) segment with yellow. Most individuals have white (more rarely yellowish) hairs on the apical terga (i.e. abdominal tip). Subspecies *occidentalis* is the most colour variable. Subspecies *mckayi* consistently has yellow hairs on the third abdominal segment (Figure 3).

Figure 1. Female (worker) Western Bumble Bee *occidentalis* subspecies (note there is more than one form, and this photo is considered the typical form). Photo by Sheila Colla. Specimen housed at the Packer Bee Collection, York University, Toronto.

Males: Similar in appearance to females, with variability in colour pattern (Figure 2), and intermediate in body size (1-2 cm length). Male-specific colouring includes the pale yellow hairs intermixed with black hairs on the face. The malar space is short.

Figure 2. Male Western Bumble Bee *occidentalis* subspecies (note there is more than one form, and this photo is considered the typical form). Photo by Sheila Colla. Specimen housed at the Packer Bee Collection, York University, Toronto.

Figure 3. Female (worker) Western Bumble Bee *mckayi* subspecies (*Bombus occidentalis mckayi*). Photograph by Cory Sheffield. Specimen housed at the Royal Saskatchewan Museum, Regina, Saskatchewan.

A full account of the different adult colour variants of Western Bumble Bee is shown in Koch *et al.* (2012) and Williams *et al.* (2014). Bumble bees (and this is true for most bees) are not typically observed or identified by their immature life stages (i.e., egg, larvae, pupae). These stages are largely unobserved for most bees and the nesting biology and immature stages of most bee species have not been studied. General accounts of the life stages of bees are found in Stephen *et al.* (1969) and Michener (2007). Stephen and Koontz (1973a, 1973b) provided more discussion specific to the larval stages of bumble bees. The immature life stages of Western Bumble Bee are not described in the literature, and species-specific characters are largely lacking within genera.

Population Spatial Structure and Variability

Genetic diversity and population stability in US populations of Western Bumble Bee (applicable to subspecies *occidentalis*) were recently studied using 8-11 microsatellite loci (Cameron *et al.* 2011). Results suggest this subspecies has low among-subpopulation genetic diversity (n=93, loci = 8, total H_E=0.584) and may be susceptible to steeper population declines than other bumble bee species studied due to increased inbreeding potential and genetic drift in small effective populations.

Many specimens of Western Bumble Bee from throughout its natural range have had DNA barcodes (i.e., COI) sequenced, which are available on the Barcode of Life Data Systems (BOLD) (see Williams *et al.* 2012). These sequences were used to support the designation of two subspecies: *B. o. mckayi* and *B. o. occidentalis* (Williams *et al.* 2012). Further morphological and biogeographical data supporting the two subspecies of Western Bumble Bee recognized by Williams *et al.* (2012) were presented by Sheffield *et al.* (2013); these data are also currently under preparation for publication (Sheffield *et al.* in prep.).

Designatable Units

Two designatable units are proposed based on the subspecies recognized by Williams *et al.* (2012). In Canada, subspecies *occidentalis* occurs within the COSEWIC National Ecological Areas - Pacific, Southern Mountain, Prairie, and the southernmost part of the Northern Mountain (COSEWIC 2010). Subspecies *mckayi* occurs in the COSEWIC Northern Mountain National Ecological Area, though may extend into the far northwestern area of the Boreal National Ecological Area. The two subspecies appear to have a morphological, molecular and ecological division between 55°N and 60°N (Sheffield pers. data) (see Distribution) supporting two designatable units.

Special Significance

Prior to its decline, Western Bumble Bee was considered one of the most commonly observed bumble bees within western Canada (Hobbs 1968; Richards 1978). Like all bees, Western Bumble Bee is ecologically significant, providing pollination services to various native plant species throughout its range (see Ascher and Pickering 2013 for plant list). Bumble bees are active throughout the growing season, flying during inclement weather conditions often not suitable for most other insects (Heinrich 2004). As pollinators, bees facilitate plant reproduction, which ultimately provides shelter and food for other animals, as well as sustainability of native ecosystems (Goulson 2010; Heinrich 2004). Extensive background on the ecosystem goods and services of bumble bees is written in Goulson (2010) and Heinrich (2004).

Managed bumble bee colonies are shipped throughout the globe and used to pollinate greenhouse crops (e.g., cucumbers, sweet peppers, and tomatoes) (Patten *et al.* 1993; Macfarlane and Patten 1997). These crops are grown and flower year round and require continuous pollination. Western Bumble Bee was once available as a managed pollinator for greenhouse pollination in North America before problems rearing the species in captivity arose in the early 2000s (e.g., Whittington and Winston 2003). Up to this time, commercial bumble bee producers (i.e. Koppert® and BioBest®) reared Common Eastern Bumble Bee (*B. impatiens*) for pollination in eastern North America, and Western Bumble Bee for the west. At present, only Common Eastern Bumble Bee is available for greenhouse pollination in North America, and no restrictions prevent the importation of Common Eastern Bumble Bee to greenhouses for pollination services throughout Canada; it is used in BC, where it has established feral populations (Ratti and Colla 2010). Common Eastern Bumble Bee is suspected to be shipped for use in private greenhouses in Northwest Territories (Carriere pers. comm. 2014). Some states, such as Oregon, have banned the importation of extralimital species of *Bombus* (i.e. Common Eastern Bumble Bee).

Bees provide pollination services for wild fruit production and natural ecosystem sustainability. See Ascher and Pickering (2013) for a partial list of plant genera/species visited by Western Bumble Bee. Bees are also of high cultural significance to Aboriginal groups. Some of the noted plants visited by Western Bumble Bee that are of importance to First Nations people include species in the aster family (Asteraceae; e.g., *Helianthus*), honeysuckle family (Caprifoliaceae), blueberry family (Ericaceae; Vaccinium spp.), rose family (Rosaceae; *Rosa* spp., *Rubus* spp.), and many others (Turner 1975).

The subgenus *Bombus sensu stricto* in North America is represented by five species (just over 10% of the 46 species; Williams *et al.* 2014). For reasons that are not clear (though highly overlapping areas of high urbanization/agriculture) the subgenus shows a higher inherent risk of vulnerability than any other subgenus on the continent — four of the species are currently of concern. Two of the species are considered at risk: the Rusty-patched Bumble Bee (*Bombus affinis* Cresson) was assessed as Endangered by COSEWIC (2010), and Franklin's Bumble Bee (*B. franklini* Frison; found in USA only) could possibly be extinct as it has not been seen since 2008. The Yellow-banded Bumble Bee (*B. terricola* Kirby) is currently having a COSEWIC report prepared. In addition, Western Bumble Bee is host to two cuckoo bumble bees: Gypsy Cuckoo Bumble Bee (*B. bohemicus* Cresson) and Suckley's Cuckoo Bumble Bee (*B. suckleyi* Greene), the former of which appears to have undergone significant declines.

DISTRIBUTION

Global Range

Western Bumble Bee ranges in western North America (Figure 4 and Figure 5). Subspecies *occidentalis* ranges from central California (CA) north to central British Columbia (BC), east in Alberta (AB), southern Saskatchewan (SK), and south through North Dakota (ND), South Dakota (SD), Idaho (ID), Montana (MO), Wyoming (WY), Utah (UT), Colorado (CO), New Mexico (NM), northern Arizona (AZ) and Nevada (NE). Subspecies *mckayi* ranges from northern BC, north into Yukon (YT), western Northwest Territories (NT) and Alaska (AK). The species has been recorded from elevations at sea level to 1350 metres, although the elevations of collection sites vary with latitude: the species ranges at higher latitudes in southern parts of its global range.

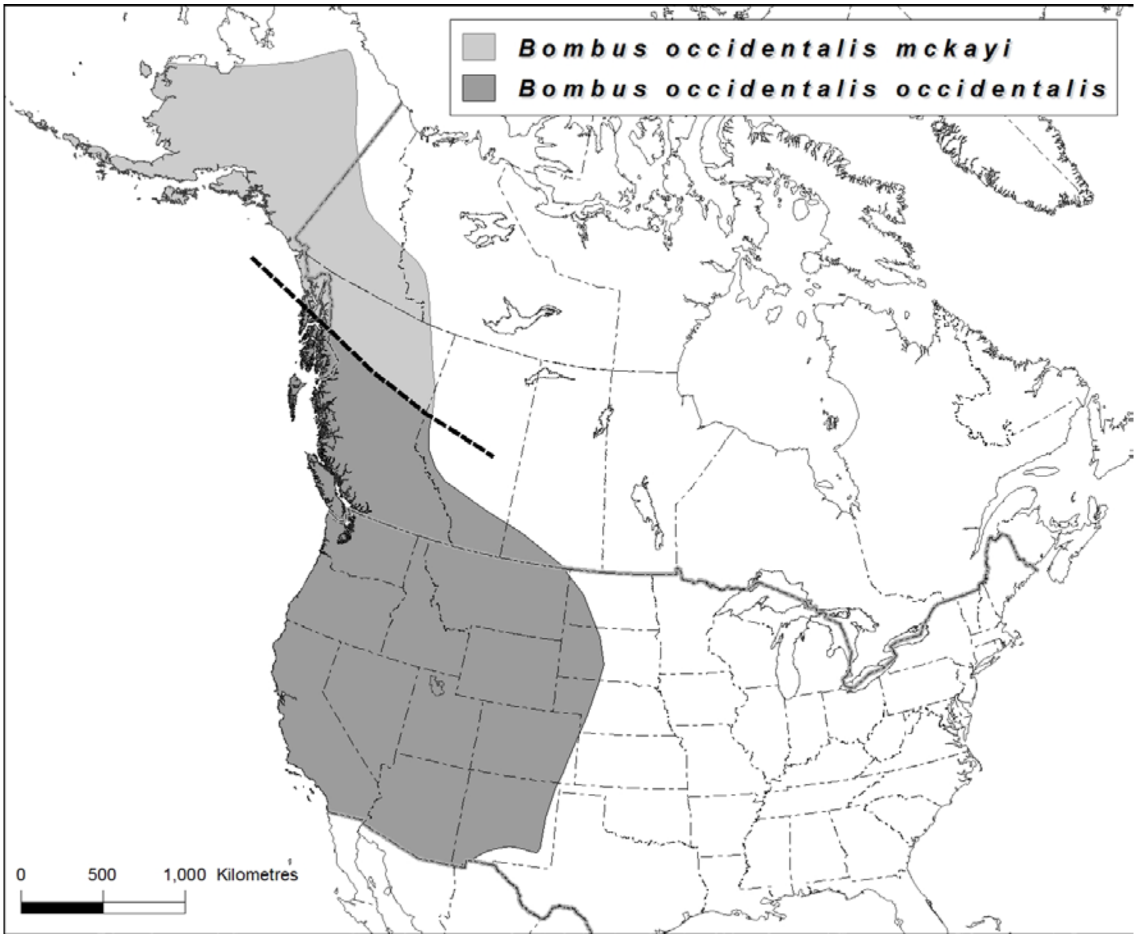

Figure 4. Global range map of *Bombus occidentalis* showing the distribution of both subspecies, *B. o. occidentalis* (below line) and *B. o. mckayi* (above line). Note that the southern boundary of *B. o. mckayi* and the northern boundary of *B. o. occidentalis* are not well-defined. Map created using data from Sheffield *et al.* 2013, and Sheffield *et al.* in prep.

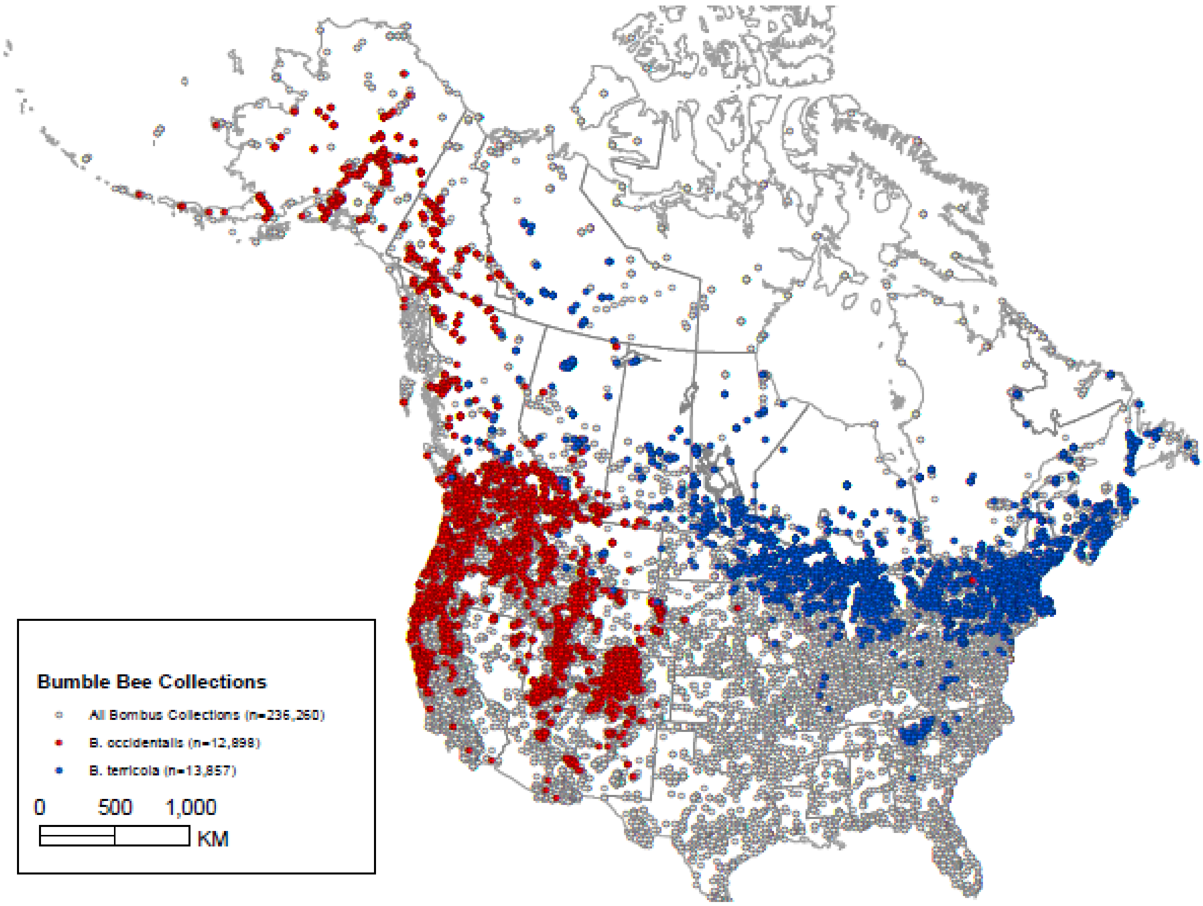

Figure 5. Bumble bee collection points (all dots total 236,260) for North America from 1892 - 2012. Red dots = Western Bumble Bee (*Bombus occidentalis* (12,898 records) both subspecies); blue dots = closely related Yellow-banded Bumble Bee (*B.terricola*) (13,857 records) including regions of overlap (see Wildlife Species Description and Significance). Note there have been taxonomic issues with *B. occidentalis* and *B. terricola,* and it is not guaranteed that all specimens used in these maps are correctly identified. The one eastern specimen of *B. occidentalis* is presumed to be an error. These maps should be used as general range maps and outliers further investigated. No data exists for areas without points. More than 70 individuals and institutions contributed to the dataset, and are listed at: www.leifrichardson.org/bbna.html. Map compiled by Leif Richardson. Specimens compiled in a dataset for Williams *et al.* 2014.

Canadian Range

Subspecies *occidentalis* ranges within western Canada throughout southern BC to ca 55°N and west through southern AB and SK. Subspecies *mckayi* ranges north of ca 55°N within BC, YK, and likely western NT (Sheffield *et al.* in prep) (Figure 4 and Figure 5).

Extent of Occurrence and Area of Occupancy

Extent of occurrence (EO) for the two Western Bumble Bee subspecies are approximate: subspecies *occidentalis* is 720,170 km^2 and subspecies *mckayi* is 623,837 km^2. There are some minor uncertainties in delimiting the range interface between subspecies *occidentalis* and *mckayi* due to insufficient sampling in this critical range (Sheffield pers. comm. 2013).

An index of area of occupancy (IAO) is not possible to calculate. The population size and the widespread, scattered records across a large area suggest the IAO values for both subspecies to be > 2000 km^2.

Search Effort

Museum and collection records for Western Bumble Bee date from 1882 to 2013. Bumble bee collection events for North America were plotted and represent both indirect and direct search effort for Western Bumble Bee (Figure 5, all dots total 236,260; all *Bombus*). Surveys have not been systematic or comprehensive over time and across the range of Western Bumble Bee; however, it is assumed if the species were present it would have been collected during bumble bee collection events. There are large areas and time periods with little data.

Search effort for bumble bees (as a group) in some areas of North America has been extensive in the past decade. Search effort in the past ten years within the range of Western Bumble Bee is partially summarized below by province and listed in Table 2.

<u>British Columbia:</u>

Within the range of subspecies *occidentalis*, surveys from 2009 - 2013 recorded specimens from southern Vancouver Island, lower mainland, lower Fraser Valley, Okanagan region, and the Kootenay region (Table 2). Cumulative search effort in 2010 found only 17 observations over extensive surveys (> 575 hours; > 115 sites and > 800km) (Table 2).

In the past decade, there have been minimal surveys or bumble bee collection events from the central and northern parts of British Columbia. In 2013, surveys (minimum of 281 hours cumulative search effort over approximately 104 sites; additional sites and samples are still being processed) were conducted in BC (Sheffield *et al.* 2013; data being used in a manuscript in prep.). These surveys yielded a minimum of 6447 *Bombus* specimens (additional samples are still being processed), of which 115 specimens (or 1.7% of total examined) were Western Bumble Bee (Sheffield *et al.* in prep.), which was recorded at only 36 of at least 104 sites (sites are still being tallied) (Sheffield pers. data 2013).

Alberta:

During the 1960s and 1970s, researchers investigating bumble bee ecology placed thousands of artificial nests in natural areas in southern Alberta, attracting hundreds of Western Bumble Bee queens (Hobbs 1968; Richards 1978). During the spring of 1985 and 1986, researchers engaged in daily collecting of all local *Bombus* queens in the Calgary and Kananaskis Valley regions of southern Alberta, resulting in well over 200 queens each year, and a total of 126 Western Bumble Bee records (Owen 1988). During the summers of 1997-2000, researchers conducted regular sampling of bumble bee workers and males in the Kananaskis Valley and southern Alberta, collecting over 700 Western Bumble Bee records (Otterstatter and Whidden 2004). The later work in Kananaskis (1985-2000) represents at least 1500 person-hours of collecting.

Search effort in the past decade has been minimal. In 2007 surveys in southeastern AB recorded Western Bumble Bee in the Cypress Hills (ca. 60 queens; Sheffield pers. data). In 2013, surveys were conducted in four areas of the province. Specimens were collected, albeit uncommonly from near Dinosaur Provincial Park, Red Cliff (south of Medicine Hat) and Cypress Hills areas (Sheffield pers. data). No Western Bumble Bee was recorded in 2013 surveys around Edmonton (Sheffield pers. data), though this area is thought to be out of the range of this species.

Saskatchewan:

There are few historic surveys or museum collections from SK. Recently subspecies *occidentalis* (i.e., 2012-2013) has been recorded in the southern third of SK. Extensive, summer-long insect surveys were conducted by the Royal Saskatchewan Museum in four geographic areas in southwestern SK (i.e., Grasslands National Park, Saskatchewan Landing Provincial Park, Great Sand Hills, Big Muddy Valley, and Cypress Hills Provincial Park). Subspecies *occidentalis* was detected in several of these sites, and in other parts of the province, though the samples are still being processed (Sheffield pers. comm.). The subspecies appears rather uncommon compared to other bumble bees (Sheffield pers. comm. 2013). Prior to these surveys, there are no historic records databased from these areas although this subspecies may not have been as common on the prairies as in western parts of its range.

Yukon:

Bumble bee surveys along major highways have been ongoing for the past three years, for a minimum for four days each year. Subspecies *mckayi* was present at many sites surveyed in 2009, 2010 and 2013 (Cannings pers. comm. 2013; Sheffield pers. comm. 2013). Subspecies *mckayi* is still considered common in adjacent Alaska, where in one study it accounted for over 30% of all bumble bees observed (Koch and Strange 2012). Prior to these surveys there are very few records from Yukon.

Northwest Territories:

Very few records exist for subspecies *mckayi* in the NT, these from the extreme western part of the jurisdiction. There is only one record from pre-2011 (August 4, 1944 – exact location not given). The remaining eight specimens are from various sites on the South Nahanni River, collected on various dates in August 2011 (Stotyn and Tate 2012).

HABITAT

Habitat Requirements

Western Bumble Bee requires habitat with abundant floral resources and suitable nesting sites. The species is a habitat generalist, inhabiting open coniferous, deciduous and mixed-wood forests, wet and dry meadows, montane meadows and prairie grasslands, meadows bordering riparian zones, and along roadsides in taiga adjacent to wooded areas, urban parks, gardens and agricultural areas, subalpine habitats and more isolated natural areas.

There are few studies on natural nesting preferences of Western Bumble Bee. In Alberta, Hobbs (1968) attracted 37 queens to nest in underground artificial nests. Three additional queens established colonies in aboveground nest boxes, indicating a preference for underground nests (supported by Kearns and Thomson 2001), but also suggesting some behavioural plasticity (Hobbs 1968). Similarly, Richards (1978) placed artificial nests in a variety of habitats in southeastern Alberta and found that 88 Western Bumble Bee queens (12% of 709 queens across 15 *Bombus* species) established nests. The best location for Western Bumble Bee was in underground nests connected to the surface with downward-sloping tunnels (open west-southwest) (Hobbs 1968). Queens exhibited a clear preference for wooded and transitional (wooded to meadow) nesting areas over open meadows (Richards 1978).

All bumble bees hibernate as solitary mated queens and usually overwinter by burrowing in loose soil or rotting trees (Benton 2006). Hobbs (1968) describes one Western Bumble Bee hibernaculum two inches deep in the steep west slope of a mound of earth.

Habitat Trends

In general, bumble bees require floral resources, suitable nest sites at which a colony can thrive over a season, and protected overwintering sites. No studies have specifically related habitat trends to Western Bumble Bee populations. However, widespread and cumulative habitat conversion has likely caused a decline in portions of its range. The major urban centres of the lower mainland, greater Victoria area and Calgary, combined with the large-scale agriculture within these areas, have led to cumulative habitat quality decline.

Subspecies *occidentalis*:

Habitat fragmentation, new agricultural development, including the conversion of insect-pollinated crops to wind-pollinated or greenhouse systems), and/or agricultural intensification, possibly in combination with increased pathogen rates, have likely contributed to the decline of this subspecies in much of its range in southwestern Canada (primarily BC and western AB).

In more recent decades, agricultural development in southern BC and AB has led to declines in wildlife (including pollinator) habitat suitability (see Javorek and Grant 2011). Logging, grazing and drying out of wetlands may have adversely altered suitable habitats. In AB, for example, the foothills habitat of Western Bumble Bee is changing at a rapid pace due to substantial energy and forestry industry development, as well as intensification of recreational use, agriculture, and acreages. These uses create significant land and water disturbance and habitat fragmentation (Gardner 2007), and presumably have negative effects Western Bumble Bee.

This subspecies may not have been as common on the prairies as in western parts of its range. Much of the natural prairie habitat conversion occurred decades ago, and there are few historical Western Bumble Bee records. For this reason it is difficult to assess trends.

Subspecies *mckayi*:

Habitat does not appear to have substantially changed historically, although the cumulative effects of resource development and climate change may lead to changes in the timing of the floral resources necessary to sustain populations over the season.

BIOLOGY

Information is compiled from general bumble bee references (Alford 1975; Goulson 2003; Benton 2006) and where applicable references are provided specifically for Western Bumble Bee.

Life Cycle and Reproduction

Western Bumble Bee is a primitively eusocial species with queen and worker castes, where the workers are the offspring of the founding queen and together live in a colony. Colonies are annual, with one generation per year. Mating occurs in the fall, males die and only the queen overwinters and emerges in the spring to found a new colony.

Queens typically emerge from April to May and immediately start looking for suitable nest sites. Nests are established in abandoned rodent burrows, grassy hummocks, rotted logs or openings in dead wood. Queens in southern parts of its range emerge sooner than in northern parts, and depending on the temperature and climate, queens will emerge at different times. Queens from Alberta established nests in mid- to late May (Hobbs 1968).

A few weeks after the queen's initial egg-laying period, female workers emerge and begin foraging for the colony and feeding the brood. As summer progresses the colony reaches maximum worker production and begins producing males and potential queens. These reproductive individuals leave the nest and mate. After mating, young queens enter diapause and overwinter. The old queen, the males and workers decline as fall approaches, and ultimately die with the first frost. Little is known about mating behaviour and colony dynamics in Western Bumble Bee. In the closely related Common Eastern Bumble Bee, females mate with a single male during a single mating event and, as with all bees, the sperm is stored in a spermatheca until used in fertilization (Greeff and Schmid-Hempel 2008).

Eggs hatch after approximately four days and larvae feed on pollen and nectar brought to the nest by workers. The larval stage of bumble bees has four instars. After almost two weeks larvae spin cocoons and pupate. Pupae develop for two weeks before hatching as adults. In total, development from egg to adult takes approximately five weeks, but varies with temperature and food supply (Alford 1975). Western Bumble Bee is a pollen-storer, meaning the larvae live in cells and are fed individually by adults that open the brood clump regularly as the larvae develop. Pollen-storing adults emerge relatively equal in size compared to pocket-making bumble bee species, in which workers vary greatly in size due to unequal food distribution within the brood clumps. Western Bumble Bee queens may require more pollen than other bumble bee species to initiate worker production (Hobbs 1968).

Predation and Parasitism

A wide variety of invertebrates parasitize Western Bumble Bee at all stages of the colony cycle (Schmid-Hempel 1998). Spring queens can be infected by nematodes (*Sphaerularia bombi*) or protozoa (*Apicystis bombi*) rendering them incapable of founding colonies. During the summer, workers may acquire parasites (e.g., *Crithidia bombi*), while foraging on flowers contaminated by infected bees.

Cuckoo bumble bees (subgenus *Psithyrus*) specialize in usurping queens. Adult females enter the colony, occasionally killing the queen, and lay their own eggs, which are cared for by the remaining host workers. Western Bumble Bee is host to two cuckoo bumble bees: Gypsy Cuckoo Bumble Bee (*B. bohemicus* Cresson) and Suckley's Cuckoo Bumble Bee (*B. suckleyi* Greene).

The internal mite *Locustacarus buchneri* is a common parasite that lives within the respiratory tubes of most (perhaps all) *Bombus* species. A survey in southern Alberta showed this mite primarily occurs in Western Bumble Bee, with up to 50% of queens and workers infected (Otterstatter and Whidden 2004). The reasons for this specificity are unclear; however, this parasite may pose a threat to Western Bumble Bee populations.

Nosema bombi is a microsporidian gut and tissue parasite of bumble bees. *Nosema bombi* is considered low among wild bumble bees in Canada (average infection rates = 5-10%), but recent field surveys across the United States (Cameron *et al.* 2011) found the highest levels of *N. bombi* infection (i.e., over 35%) among declining bumble bee species, particularly Western Bumble Bee, which supports the hypothesis that this parasite is a serious threat. However, Koch and Strange (2012) found similarly high rates (i.e., 44%) in Western Bumble Bee (subspecies *mckayi*) in Alaska where it remains the most common bumble bee recorded in this area. As such, high rates of *Nosema* infection may be part of the normal host-pathogen dynamics of Western Bumble Bee (Koch and Strange 2012) and declines in subspecies *occidentalis* may involve multiple cumulative threats (see above). However, this pathogen is believed responsible for the mid-1990's collapse of commercial Western Bumble Bee in North America (Thorp and Shepherd 2005).

Predators of adult Western Bumble Bee include robber flies (Family Asilidae) and crab spiders (Family Thomicidae). Thickheaded flies (Family Conopidae) are parasitoids of adult bumble bees. Raccoons, skunks, bears and other mammals are known to destroy and consume bumble bee colonies (Breed *et al.* 2004).

Physiology and Adaptability

Bumble bees overwinter as adult queens, which emerge early in the spring and require early flowering plant species to initiate the colony, and additional floral resources for colony development throughout the spring and summer months. As these bees are obligatorily social, they are dependent on diverse plant communities, requiring ample pollen and nectar resources throughout the active period of the colony. Therefore, only habitats supporting rich plant communities provide the nutrition to support bumble bee colonies.

Bumble bees are found throughout most of Canada, and many (including Western Bumble Bee) appear to be relatively cold-tolerant during the active adult period, having been found at elevations as high as 3800 m in southern parts of its global range (USDA 2010). Bumble bees have the physiological capability to thermoregulate (Heinrich 2004); they are able to "shiver" to generate heat in their thoracic muscles to warm up to reach the required minimum body temperature (approx. 30°C) during low ambient temperatures (Heinrich 2004). Given that bumble bees fly in the spring and fall in temperate and arctic regions, internal temperatures generated by shivering can be well above ambient temperature. Since Western Bumble Bee is an early emerging species and occurs at high latitudes and altitudes, thermoregulation is likely an extremely important adaptation.

Dispersal and Migration

There is little information on natural dispersal rates for bumble bees. Dispersal occurs primarily in spring by queens while searching for suitable nest sites (Goulson 2003). There is some evidence that bumble bees are able to disperse relatively long distances. Males of the closely related Buff-tailed Bumble Bee (*B. terrestris*) are reported to fly between 2.6 and 9.9 km from the colony of origin (Kraus *et al.* 2008). Buff-tailed Bumble Bee was introduced to Tasmania in the early 1990s and has since spread at a rate of approximately 10 km per year (Stout and Goulson 2000). Dispersal is likely important to survival based on studies that have examined the patchiness of bumble bee habitat (e.g., Hatfield and LeBuhn 2007) and increased problems associated with small effective population sizes in haplodiploid insects (Zayed and Packer 2005) (see Limiting Factors).

Interspecific Interactions

Western Bumble Bee is a generalist forager; it naturally co-forages and competes with many other bee species for food pollen and nectar. This species also can nectar-rob (i.e., carry out illegitimate flower visits usually not resulting in pollination; bees bite holes in the base of flowers to reach the nectar without contacting the anthers and/or stigma) allowing workers to forage for nectar from long-tubed flowers. This allows the species to feed for nectar on a large variety of flowering plant species.

Western Bumble Bee likely has important mutualistic relationships with many early spring and montane meadow flowering plant species, which may rely on it and other bumble bee species for pollination. However, the extent of interdependence of individual plant species on Western Bumble Bee for pollination is unknown. Where its range overlaps with the closely related Yellow-banded Bumble Bee, Western Bumble Bee is usually more common in montane habitats and Yellow-banded Bumble Bee more common at lower elevations (Hobbs 1968), though both species are sympatric in parts of the prairies.

Western Bumble Bee is host to Gypsy Cuckoo Bumble Bee and Suckley's Cuckoo Bumble Bee (see Predation and Parasitism).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Four different datasets are used to show declines in the relative abundance of Western Bumble Bee. Relative abundance (RA) is the number of individuals of one species (e.g., Western Bumble Bee) divided by the total number of individuals (e.g., *Bombus*) collected, and is often used as a proxy of abundance when data are not amenable to other analysis. The RA is also used as an index of search effort for Western Bumble Bee, and it is assumed that if the species was within an area during a collection event, that it would likely have been collected. It is noted that measuring the RA of a species may not reflect actual population abundance. For ease of reference between the next sections, these studies are numbered.

1) The first study uses a dataset of bumble bees for Canada, with 44,706 museum and observation records databased, ranging in dates from 1882 – 2011 (this dataset does not yet include data from 2012 and 2013 [e.g., from Sheffield *et al.* in prep.]). The RA of Western Bumble Bee was plotted in ten-year increments and for each jurisdiction where found in Canada (Table 3; Figure 9 and Figure 10).

2) In a second study (and using an older and less complete version of the dataset of bumble bees mentioned above), Canada-based distribution data were mapped on a 50 x 50 km grid, from 1882-1995 and 1996-2010 (including non-independent samples and sites where multiple observations were recorded within a year). Figure 6 is the graphical representation of this data.

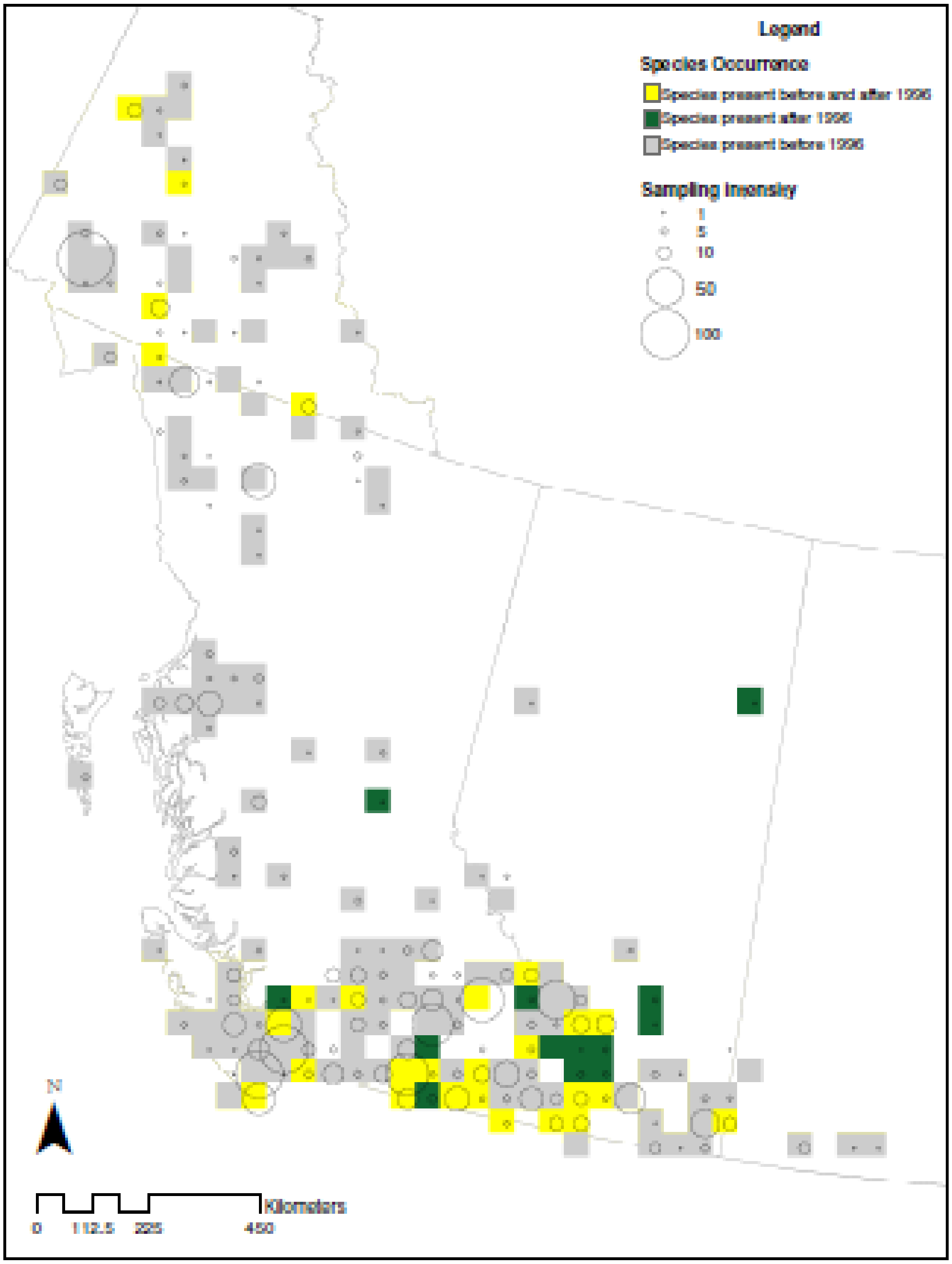

Figure 6. Spatial distribution of sampling records of Western Bumble Bee in Canada from 1882 - 2010. Each circle is proportional to the number of observations recorded at that site between 1882 and 2010, inclusive (including non-independent samples and sites where multiple observations were recorded within a year). Data are mapped on a 50 x 50 km grid. Grey squares show records prior to 1996 (128 squares); yellow squares show sites collected pre/post 1996 (27 squares); green squares show collections after 1996 (13 squares) (n= 1706 specimens). Data is compiled from CBIF and contributors listed in the Acknowledgements section. This map is not possible to update.

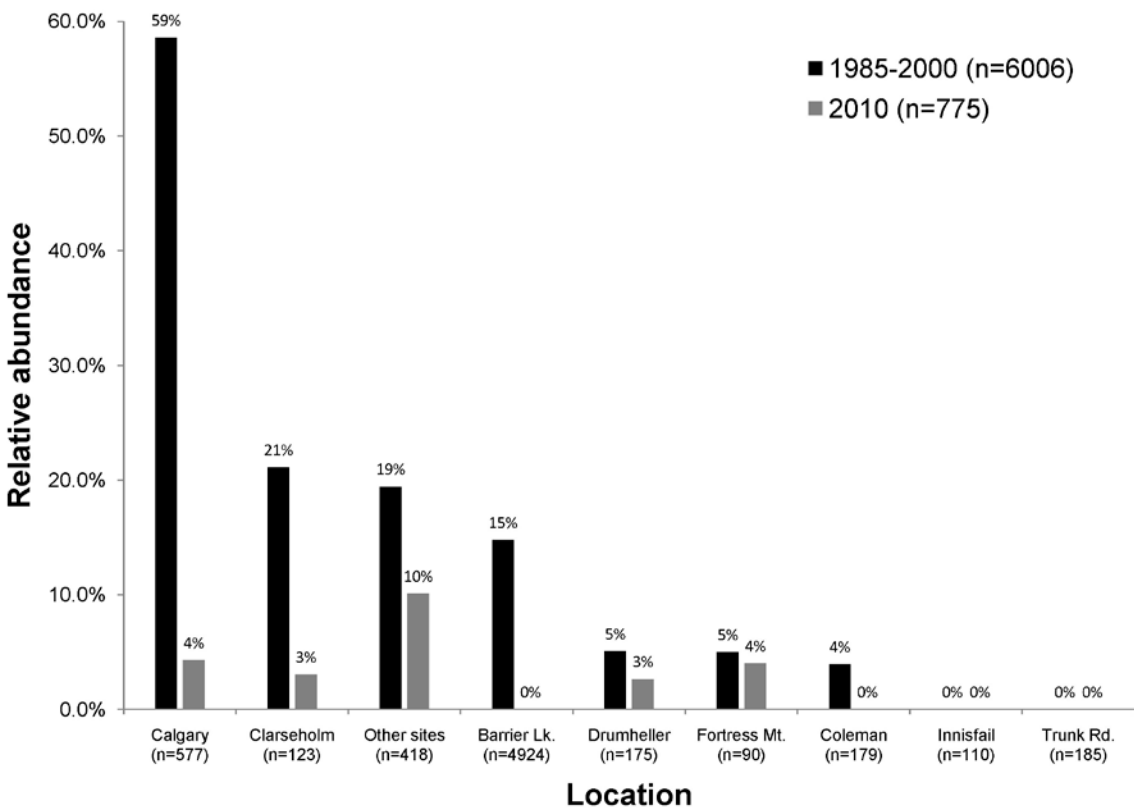

Figure 7. Relative abundance (RA) of Western Bumble Bee across southern Alberta during two time periods (combined sample sizes shown in parentheses). All data from southern Alberta are included (i.e., surveys of 2000 and 2010, as well as the additional study sites sampled at other times). Except for two sites where Western Bumble Bee did not occur in either period (Innisfail and Trunk Rd.), RA declined from 2000 to 2010. Habitats in which the species was collected are: Calgary (urban), Clarseholm (rural), Barrier Lk. (natural), Drumheller (edge of species' range), Fortress Mt. (higher elevation), Coleman (rural), and Innisfail (out of subspecies' range) and Trunk Rd. (out of subspecies' range).

Two additional studies, one in southern AB and one in the Fraser Valley of BC, are regional in scope and used to show RA declines within each respective region. Note that specimens collected during these studies are assumed to be subspecies *occidentalis* based on the geography of the collection sites.

3) The southern Alberta study compares data collected in 1985-2000 and repeats similar data collection methods at these sites in 2010. The Fraser Valley study compares populations in 1981-82 with those in 2003-04. During preparation of this status report, these studies were analyzed to determine changes in the RA of Western Bumble Bee over time. The proportion of the total bee catch composed of Western Bumble Bee was analyzed using logistic regression and included time period (early or late years of the study) and study site (for the southern Alberta surveys only). This approach estimates the change over time in the probability of collecting Western Bumble Bee at a study site.

In the Alberta study, bumble bee workers and males were surveyed at eight sites across southern Alberta during the summer of 2000 (all species n=1672), and repeated using the same methods at the same sites in 2010 (n=775). Details of the 2000 survey are published elsewhere (Otterstatter 2001), whereas the second survey was conducted specifically to provide information for this report (surveys conducted by R. Owen [pers. data]; R. Longair [pers. data]). Collecting locations, seasonal timing and search effort was the same in both 2000 and 2010; and both studies are considered highly comparable.

These data were supplemented with additional surveys conducted in the same geographic region, but at different times or at different sites. These additional data include: a 1985-86 study of bumble bee queens (n=442) in the Kananaskis Valley and Calgary areas (Owen 1988); intensive surveys of bumble bees near Barrier Lake, Kananaskis, during 1997-2000 (n=4376) and in Calgary during 1998 (n=367) (Otterstatter *et al.* 2002; Otterstatter 2004; Otterstatter and Whidden 2004); a study of pollen foraging by bumble bee queens and workers (n=99) at three sites in the foothills of southwestern Alberta during 1991-92 (Rasheed and Harder 1997); and opportunistic surveys of workers and males (n=109) at five sites in southern Alberta during 2000 (R. Owen pers. data).

4) In the Fraser Valley, wild bumble bees were collected in commercial berry fields in 1981-82, and again in 2003-04 (details in Winston and Graf 1982; MacKenzie and Winston 1984; Ratti 2006; Ratti *et al.* 2008; Colla and Ratti 2010). In the recent study twelve sites were surveyed using sweep nets and pan traps. Both studies (1981-82 and 2003-04) were carried out in the same area, with similar methods and are considered highly comparable.

Abundance

1) The RA of Western Bumble Bee appears to decline within each jurisdiction (Table 3, Figure 9) and overall when all records are combined across the species' range in Canada (Table 3; Figure 10). In BC, the RA declines from approximately 43% (1992 – 2001) to 3% within the last ten-year increment (2002 – 2011) with an overall decline of more than 85%. In AB, RA of Western Bumble Bee declines from 83% (1992 – 2001) to less than 10% (2002 – 2011). In SK, in general there are few historical records of bumble bees; however, there is a decline in RA from 9% to 3% within the last ten-year increment.

2) This study shows the spatial distribution of sampling records of Western Bumble Bee in Canada from 1882 – 2010 (Figure 6). Each circle is proportional to the number of observations recorded at that site between 1882 and 2010, inclusive (including non-independent samples and sites where multiple observations were recorded within a year) (n= 1706 specimens). Grey squares show records prior to 1996 (128 squares); yellow squares show sites collected pre/post 1996 (27 squares); green squares show collections after 1996 (13 squares) (n= 1706 specimens).

Two regionally specific studies show declines in RA for subspecies *occidentalis*.

3) In Alberta, RA declined from 16.9% (n=1017 [subspecies occidentalis] / 6006 [*Bombus* collected]) during 1985-2000 to 3.2% (n=25 [subspecies occidentalis] / 775 [*Bombus* collected]) in 2010 (Figure 8 and Figure 9). The highest number of Western Bumble Bee recorded in this study was at Barrier Lake (n=4924) and one of the most notable changes is the complete (or very near) disappearance of this bee from one site at Barrier Lake (Kananaskis) where it was formerly the 3rd or 4th most common *Bombus* species collected. Across six sites sampled in 2000 and again in 2010 (eight sites total but two sites excluded because Western Bumble Bee was not recorded in either time period), RA declined 80% from 14% to 0.7% in 10 years.

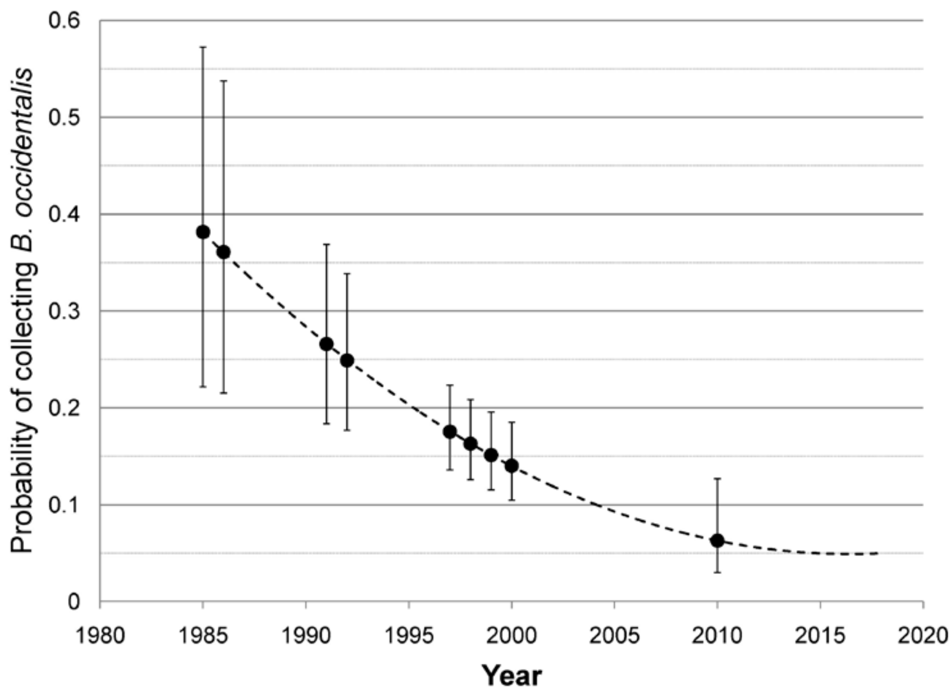

Figure 8. Predicted probability of collecting Western Bumble Bee, based on data from 14 sites in southern Alberta sampled between 1985 and 2010. Points indicate average probabilities (with 95% confidence interval) from sites sampled during a given year. Dashed line is a quadratic regression fit; between 2010 and 2018, the line represents projected values from the regression equation.

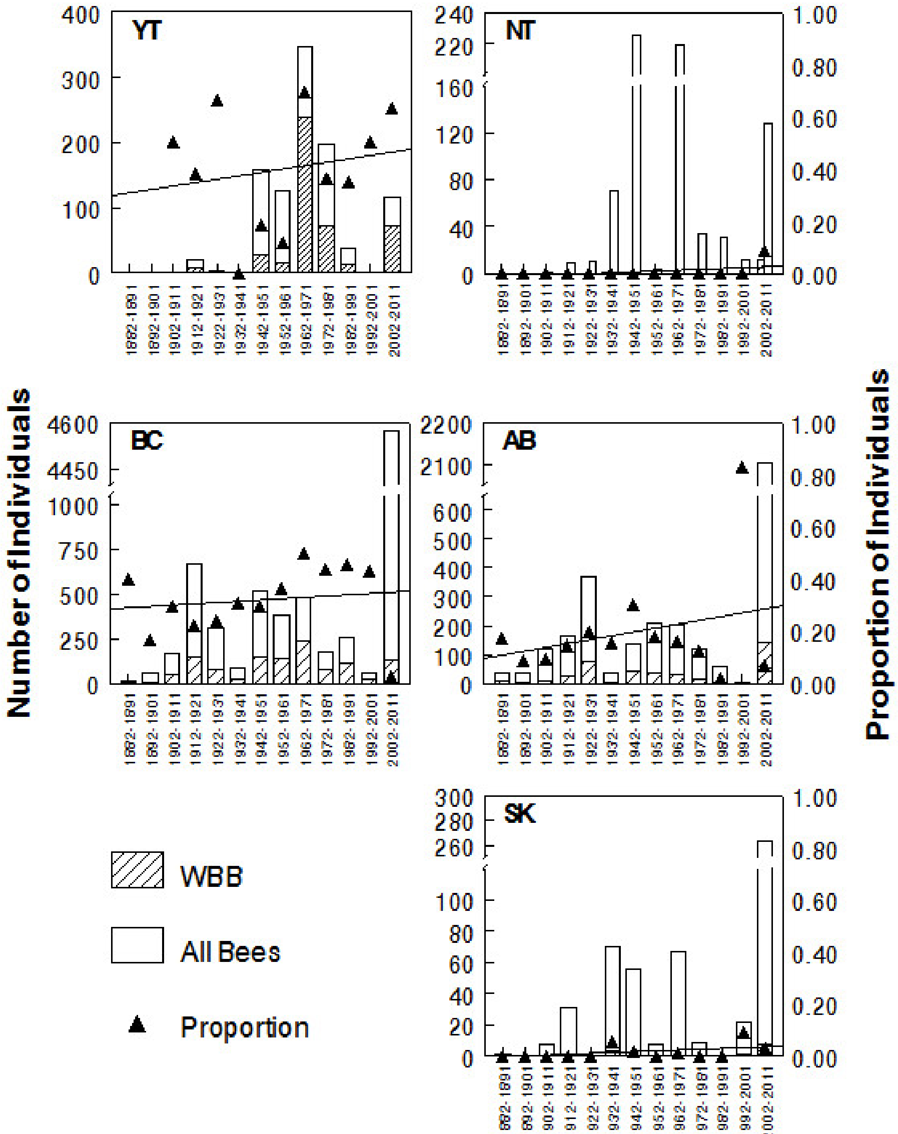

Figure 9. Relative abundance (RA) of Western Bumble Bee (WBB) based on all databased *Bombus* records in Canada (1882 – 2011). The left Y-axis (shaded portions of bars) indicates WBB specimens and the right Y-axis (triangles) represents the proportion of WBB specimens by ten-year intervals. Linear regression was used to examine trends in RA in WBB across ten-year intervals: the line represents a best fit of the data. See also Table 3. Graphs generated using Minitab ® software.

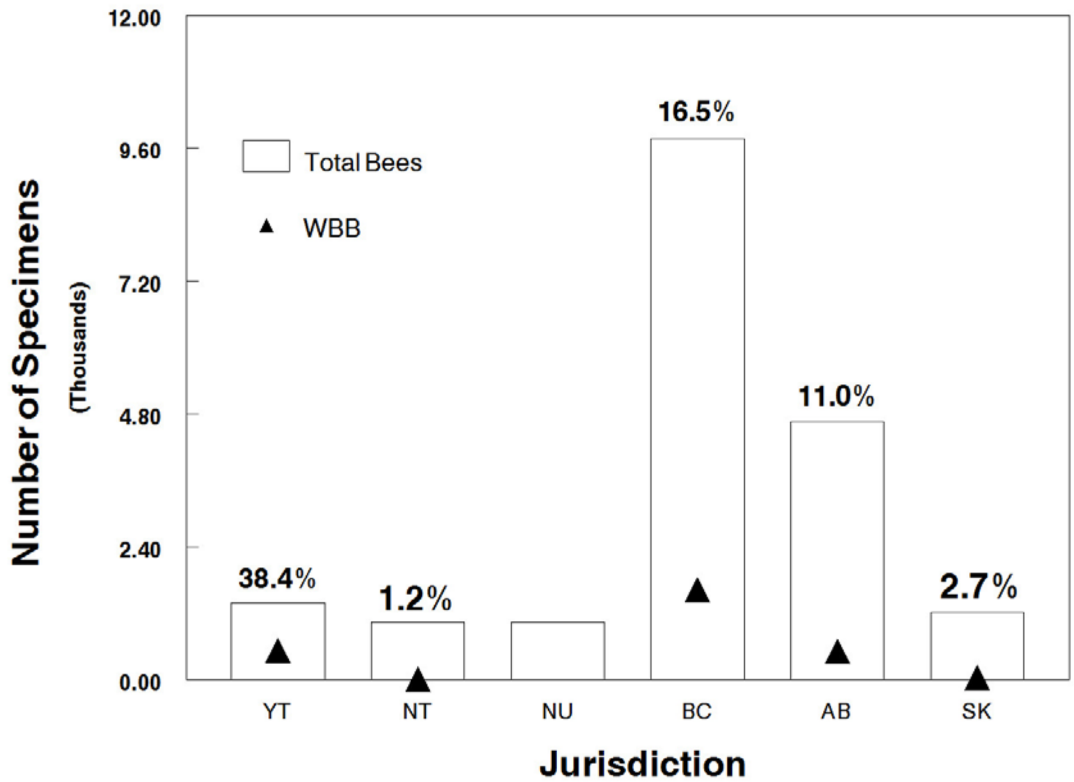

Figure 10. Total number of databased bumble bee specimens in Canada (1882 – 2011) from each province and territory; triangles represent the number of Western Bumble Bee (WBB) specimens. Values above each bar represent the percentage of specimens within the collection which are WBB. See also Table 3. Graphs generated using Minitab ® software.

Western Bumble Bee does not appear to have shifted its geographic range northward: the two northernmost sites in the AB data set (i.e. Forestry Trunk Road and Innisfail) did not record the bee in the most recent period. Classifying the sites according to ecoregion (as defined by Strong 1992) suggests that the largest declines have occurred in parkland regions (areas around and south of Calgary, RA decreased from 58.6% to 6.3%). Substantial change has also occurred in montane areas (Kananaskis Valley and areas south between grasslands and Rocky Mountains, 14.8% declined to 0%). The change observed for grasslands was less pronounced (12.7% declined to 3.1%). Subalpine habitats showed no significant change (5.0% compared to 5.2%); however, Western Bumble Bee abundance is typically low in subalpine areas.

The change in the probability of collecting Western Bumble Bee during 1985-2010 in Alberta shows a steep decline over the past 25 years (estimated from the logistic regression of Western Bumble Bee RA across all 14 sites) (Figure 8). Given that these predictions are based on data aggregated across disparate regions, the margin of error is large (as reflected by the large confidence intervals during the earliest years) and considers differences in search effort and methods. For example, the search effort in Alberta was greater during 1985-2000 (n=6006, resulting from numerous person-hours across several studies) than during 2010 (n=775, resulting from 2 collectors in a single study).

4) The study in the Fraser Valley showed RA in berry fields declined from 33.3% (n=608/1828) in 1981-82 to 0.7% (30/4221) in 2003-04 (details in Winston and Graf 1982; MacKenzie and Winston 1984; Ratti 2006; Ratti *et al.* 2008; Colla and Ratti 2010).

In the United States, population declines have occurred in some of the most historically abundant bumble bees (including Western Bumble Bee), which formerly occupied wide ranges (Cameron *et al.* 2011). Of total of 16,788 bumble bees collected throughout the United States except Alaska (e.g., within the range of subspecies *occidentalis*) from 2007-2009, only 129 Western Bumble Bee individuals were collected (Cameron *et al.* 2011). All detections occurred in the Intermountain West (i.e. region of North America lying between the Rocky Mountains to the east and the Cascades and Sierra Nevada to the west) and Rocky Mountains and the species was largely absent from the western part of its range (historically the Pacific west, CA, OR and WA) (Cameron *et al.* 2011). The detected range-area reduction in this study was estimated at 28% over more than 100 years.

Subspecies *mckayi*:

In YK and NT, RA appears stable (Table 3; Figure 10). There are few historical specimens and thus there is minimal comparable data from which to draw trends in RA. Based on 2013 surveys (at least 20 sampling sites, half hour minimum sample duration; not yet in Canadian bee dataset) this bee was recorded from many sites throughout the range in the YT (Sheffield pers. data 2013). Although known from the western NT, no trend data exists for this species as almost all of the records are from 2011 (and see Stotyn 2012).

In Alaska, Koch and Strange (2012) indicate that Western Bumble Bee is the most common bumble bee. The species commonly occurs on roadsides from taiga to boreal forests and was more abundant in August 2010 than in surveys from the same year throughout the lower western states (i.e. the range of subspecies *occidentalis*) (Strange pers. comm. 2010).

Fluctuations and Trends

Little is known about natural bumble bee population fluctuations and trends. Western Bumble Bee was formerly one of the most common bumble bees in western North America and the recent decline of subspecies *occidentalis* over much of its global range suggests that this trend is not likely a natural fluctuation.

There appears to have been a reduction in the range of subspecies *occidentalis* (i.e., based on comparisons of pre-1996 and post-1995, see Figure 6). Frequency distributions in combination with changes in spatial distribution of records suggest that declines in Western Bumble Bee occurred after the 1970s (Figure 4). However, measures for estimating sampling effort are not available; thus, spatial trends may also reflect sampling effort biases as well as spatial inaccuracies associated with data georeferencing of specimens and observations. Patterns of declines based on sites with recorded samples over the three time intervals suggest approximately 60% decline in occupied area (Table 1). Sites as a 50 km grid cell were selected to be consistent with previous *Bombus* work (e.g., Fitzpatrick *et al.* 2007). Further, the mean elevation of Western Bumble Bee records was lowest for the pre-1996 period and highest for the post-1996 period (Table 1). However the difference in mean elevation between these two periods was only ~100 m, and relative sampling intensity was not consistent across periods (n=128, 27 and 13), making it difficult to conclude a consistent trend towards higher elevations.

Table 1. Summary statistics related to area and elevation of the distribution of Western Bumble Bee across four sampling intervals spanning 1882 and 2010. See also Figure 6.

	Sampling Intervals			
	Pre-1996	**Pre-1996 and continuing**	**Post-1995**	**Current distribution (all records since 1995)**
Area (km^2)	320,000	67,500	32,500	100,000
No. of sites (each site = 50 km^2)	128	27	13	40
Mean elevation (m)	1114	1210	1218	
Elevation SD (m)	520	600	441	
Elevation range (m)	0 – 2615	20 - 2177	396 - 1920	

Rescue Effect

Large areas within the range of Western Bumble Bee in Canada are undersampled. Within respective geographic ranges for both subspecies, populations of Western Bumble Bee within suitable natural habitats could potentially disperse and recolonize areas where the bee has declined and habitat was suitable. However, the source-sink dynamics of this rescue effect are unknown. Rescue effect between subspecies *occidentalis* and *mckayi* is not applicable.

Much of the northern range of subspecies *occidentalis* in Canada is suitable and largely unmodified, though it remains undersampled. Recent (2013) survey work shows the subspecies is still present in the central interior of BC (see Search Effort) although at small proportions (1.7% of total examined in 2013 study; specimens still being processed) are Western Bumble Bee (Sheffield *et al.* in prep; Sheffield *et al.* 2013). Subspecies *occidentalis* extends into the western United States, where it has also declined (Cameron *et al.* 2011). Thus although there may be suitable habitat, the US populations may not be abundant enough to support rescue to Canadian habitats.

Subspecies *mckayi* is more commonly collected throughout its range in northern BC, YK, and western NT. Rescue effect from Alaska is possible for subspecies *mckayi*.

THREATS AND LIMITING FACTORS

The International Union for Conservation of Nature–Conservation Measures Partnership (IUCN-CMP) threats calculator (Salafsky *et al.* 2008; Master *et al.* 2009) was used to classify and list threats to subspecies *occidentalis* with an overall low threat impact (Table 3). Despite the apparent low impact, subspecies *occidentalis* appears to be declining based on abundance during recent collection events (see Search Effort and Population Sizes and Trends). It is thought that the cumulative impacts of numerous threats have contributed to the decline of the subspecies. A threats assessment for subspecies *mckayi* is not completed.

Bees are more vulnerable to habitat fragmentation than other animal species due to genetic elements inherent to haplodiploidy (Packer and Owen 2001) (see Limiting Factors). Additionally, bumble bees require large inputs of floral resources (i.e., pollen and nectar) over the entire growing season, as new queens for establishing the next generations are only produced towards the end of the colony cycle. Threats that impact floral resources, nesting sites (during the growing season) and overwintering sites can have huge impacts on local bumble bee populations.

Residential and Commercial Development (Threat 1)

Habitat loss from intensive residential and commercial developments within the urban areas may be contributing to local declines of subspecies *occidentalis*. However, there are a few recent (within the past five years) records of the subspecies in Victoria (2012), Delta (2010), and other urban areas (see Table 2). This threat only applies to the highly urban and human populated areas: BC – the lower mainland and lower Fraser valley and greater Victoria areas; AB – Calgary and surrounding areas. This threat is does not appear applicable to subspecies *mckayi.*

Table 2. Recent (since 2002) surveys targeting bumble bees within the range of Western Bumble Bee.

Province	General region	Year	Search Effort	Observations	Reference
BC	Southeastern Vancouver Island	2010	332 km 106 hours	0	Page, Lilley and Heron 2010
	Lower Mainland	2010	64 sites; 271 hours; 355 km	1 (subspecies *occidentalis*)	Parkinson and Heron 2010
	Lower Fraser Valley	2010	46 sites 18 days	6 (subspecies *occidentalis*)	Knopp, Larkin and Heron 2010
	Okanagan	2010	40 sites 158 hours 147 km	4 (subspecies *occidentalis*)	Marks and Heron 2010
	West Kootenays	2010	11 sites 19 km 40 hours	6 (subspecies *occidentalis*)	Westcott and Heron 2010
	Throughout southern parks of range in BC, AB and SK	2010	Unknown.	Yes (subspecies *occidentalis*)	Best pers. data. 2010
	Victoria area, southern Vancouver Island	2012	7 sites; all municipal parks in urban setting	9 (subspecies *occidentalis*)	Wray pers. comm. 2013
	Central interior BC	2013	281 hours	In progress, both subspecies	Sheffield pers. data 2013; Heron pers. data 2013
	Northern portions along the Alaska Highway from Fort St. John to Atlin	2013	May 28 – August 2; 55 sites; minimum ½ hour search effort per site.	Yes. Numerous specimens in YK and northern BC.	Cannings pers. data 2013
AB	Edmonton	2013	in progress	Yes, in progress (subspecies *occidentalis*)	C. Sheffield pers. data 2013
SK	Cypress Hills and well into the prairies (Leader, Eastend, Shaunovan, Swift Current, and as far east as Regina)	2013	in progress	Yes, in progress (subspecies *occidentalis*)	C. Sheffield pers. data 2013
NT	South Nahanni River from Moose Ponds to Blackstone Landing on the Liard River, including Nahanni National Park Reserve	2011	Opportunistic bumble bee collections at 19 sites from July 5 – 26.	Yes. Three *Bombus occidentalis mckayi* (of 78 collected bumble bees).	Stotyn and Tate 2012
YT	Throughout the southern portions	2013	May 28 – August 2; 16 sites; minimum ½ hour search effort per site.	Yes. Numerous specimens of *Bombus occidentalis mckayi* in YK and northern BC.	Cannings pers. data 2013

Table 3. Relative abundance (RA) of Western Bumble Bee compared with databased *Bombus* collection data (1882 – 2011) in Canada. More than 70 individuals and institutions contributed to the dataset. Specimens compiled in a dataset for Williams *et al.* 2014. RA of Western Bumble Bee is given in ten-year intervals (graphical representation in Figure 9 and Figure 10). Manitoba records are not considered natural populations. Most BC records are from the southern third of the province and considered subspecies *occidentalis*.

			YT (subspecies *mckayi*)	NT (subspecies *mckayi*)	NT (subspecies *mckayi*)	BC (subspecies *occidentalis* and subspecies *mckayi*)	AB (subspecies *occidentalis*)	SK (subspecies *occidentalis*)		Overall change in RA from previous decade
Number of specimens in database	All *Bombus*	1882-1891	0	0	1	15	39	2	57	
	WBB		0	0	0	6	7	0	13	
RA			-	-	-	0.4	0.179487	-	0.22807	
Number of specimens in database	All *Bombus*	1892-1901	0	0	0	59	34	0	93	
	WBB		0	0	0	10	3	0	13	
RA			0	-	-	0.169492	0.088235	-	0.139785	39
Number of specimens in database	All *Bombus*	1902-1911	2	1	3	166	119	8	299	
	WBB		1	0	0	49	11	0	61	
RA			0.5	-	-	0.295181	0.092437	-	0.204013	46
Number of specimens in database	All *Bombus*	1912-1921	21	9	44	668	166	31	939	
	WBB		8	0	0	149	24	0	181	
RA			0.380952	-	-	0.223054	0.144578	-	0.192758	0.055169
Number of specimens in database	All *Bombus*	1922-1931	3	10	13	313	372	0	711	
	WBB		2	0	0	76	74	0	152	
RA			0.666667	-	-	0.242812	0.198925	-	0.213783	-11
Number of specimens in database	All *Bombus*	1932-1941	1	70	15	88	39	70	283	
	WBB		0	0	0	27	6	4	37	
RA			-	-	-	0.306818	0.153846	0.057143	0.130742	-38
Number of specimens in database	All *Bombus*	1942-1951	157	226	92	513	135	56	1179	
	WBB		29	1	0	152	41	1	224	
RA			0.184713	-	-	0.296296	0.303704	0.017857	0.189992	-0.45318
Number of specimens in database	All *Bombus*	1952-1961	126	4	33	377	211	8	759	
	WBB		15	0	0	137	38	0	190	
RA			0.119048	-	-	0.363395	0.180095	-	0.250329	32
Number of	All *Bombus*	1962-	348	219	135	478	201	67	1448	

			YT (subspecies *mckayi*)	**NT (subspecies *mckayi*)**	**NT (subspecies *mckayi*)**	**BC (subspecies *occidentalis* and subspecies *mckayi*)**	**AB (subspecies *occidentalis*)**	**SK (subspecies *occidentalis*)**		**Overall change in RA from previous decade**
specimens in database	WBB	1971	239	0	0	239	32	1	511	
	RA		0.686782	-	-	0.5	0.159204	0.014925	0.352901	41
Number of specimens in database	All *Bombus*	1972-1981	198	33	1	174	120	9	535	
	WBB		71	0	0	76	15	0	162	
	RA		0.358586	-	-	0.436782	0.125	-	0.302804	-14
Number of specimens in database	All *Bombus*	1982-1991	37	31	10	253	59	1	391	
	WBB		13	0	0	115	1	0	129	
	RA		0.351351	-	-	0.454545	0.016949	-	0.329923	9
Number of specimens in database	All *Bombus*	1992-2001	2	12	0	58	6	22	100	
	WBB		1	0	0	25	5	2	33	
	RA		0.5	-	-	0.431034	0.833333	0.090909	0.33	0
Number of specimens in database	All *Bombus*	2002-2011	116	140	59	4573	2103	263	7254	
	WBB		73	12	0	128	142	8	363	
	RA		0.62931	0.085714	-	0.02799	0.067523	0.030418	0.050041	-85

Table 4. Threat classification table for Western Bumble Bee subspecies *occidentalis* (*Bombus occidentalis occidentalis*) across its geographic range in Canada and based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system. For a detailed description of the threat classification system, see the Conservation Measures Partnership website (CMP 2006). For information on how the values are assigned, see Master *et al.* (2009). Threat calculator completed by J. Heron and C. Sheffield with input from D. Fraser, S. Colla and L. Richardson.

		Level 1 Threat Impact Counts	
Threat Impact		**High range**	**Low range**
A	Very High	0	0
B	High	0	0
C	Medium	0	0
D	Low	2	2
	Calculated Overall Threat Impact:	Low	Low

	Threat Impact Reasons	Subspecies *occidentalis* is primarily threatened by the cumulative effects (in order of greatest threat): 8.1) Invasive non-native/alien species: Pathogen spillover (the use of infected commercial bumble bees [e.g., use of Common Eastern Bumble Bee in western Canada] for greenhouse pollination may facilitate pathogen spillover into wild populations of bumble bees foraging nearby. Lab studies show the parasite species *Crithidia bombi* and *Nosema bombi* (suspected) have adverse effects on *Bombus* colony-founding queens, foraging workers and entire nests. 9.3) Agricultural and forestry effluents: Imidacloprid (a neonicotinoid) pesticides are harmful at concentrations in the parts per billion (ppb). These pesticides are systemic, cumulative and travel throughout the plant, reaching pollen and nectar and are commonly used on golf courses and agricultural lands. 2.1) Annual and perennial non-timber crops: Cumulative reductions of floral resources for wild bees in landscapes dominated by monocultures, particularly those that do not require insect-pollination.

Threat		**Impact (calculated)**	**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Negligible scope because there are large areas of natural habitat where development is not ongoing. Slight severity because cumulative impacts of housing and industrial development surrounding the urban centres of western Canada, specifically in southern regions approximately 200km from the US border, often result in complete loss of habitat. However, subspecies *occidentalis* is still recorded (e.g., Victoria, Delta, Edmonton, Regina). High timing because the practice is continuing.
1.1	Housing & urban areas	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Habitat loss as a result of increased urbanization, although this only affects a small proportion of the subspecies' range.
1.2	Commercial & industrial areas	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Habitat loss as a result of increased urbanization, although this only affects a small proportion of the subspecies' range.
1.3	Tourism & recreation areas					N/A; some recreational development may cause bee habitat loss, but overall other tangential impacts may affect bee habitat (e.g., pesticide use on golf courses, water diversion, reduction of floral resources, etc.) and these threats are accounted for elsewhere in this threats calculator.
2	Agriculture & aquaculture	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Negligible scope because there are large areas of natural habitat where agricultural practices do not apply; slight severity because there are agricultural areas where bees are abundant and widespread; high timing because the practice is continuing.

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Agricultural intensification in lower elevation areas, especially within the southern parts of the range (e.g., BC - Okanagan, Kootenays, Vancouver Island, lower mainland; AB - Calgary and southern AB). Although this threat is historical, agricultural intensification has occurred within the past 25 years and resulted in lower habitat quality (e.g., see Javorek and Grant 2011). Semi-bee friendly agricultural habitats (e.g., hayfields and leafy crops) are being replaced by enclosed greenhouse crops, vineyards, and other agricultural systems that may not require insect pollination.
2.2	Wood & pulp plantations					N/A
2.3	Livestock farming & ranching					N/A
2.4	Marine & freshwater aquaculture					N/A
3	Energy production & mining					
3.1	Oil & gas drilling					N/A
3.2	Mining & quarrying					N/A
3.3	Renewable energy					N/A
4	Transportation & service corridors	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Negligible scope because there are large areas of natural habitat where road building and utility/service lines are not planned. Negligible severity because in many cases transportation corridors may leave habitat more open for bees (provided the transportation corridor is not paved). High timing because the practice is continuing.
4.1	Roads & railroads	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	The threat is considered negligible. May temporarily increase habitat adjacent to roadsides - areas need to be cleared. Although there could be cumulative herbicide impacts (this threat is captured elsewhere though).
4.2	Utility & service lines	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	The threat is considered negligible. May temporarily increase habitat adjacent to roadsides - areas need to be cleared. Although there could be cumulative herbicide impacts (this threat is captured elsewhere though).
4.3	Shipping lanes					N/A
4.4	Flight paths					N/A
5	Biological resource use	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	N/A
5.1	Hunting & collecting terrestrial animals					N/A

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.2	Gathering terrestrial plants					N/A
5.3	Logging & wood harvesting	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	The threat is considered negligible. Logging may temporarily increase available habitat if there are habitat connections.
5.4	Fishing & harvesting aquatic resources					N/A
6	Human intrusions & disturbance	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Negligible scope because there are large areas of natural habitat where recreational activities are not ongoing; slight severity because recreational activities may trample or decrease nest site suitability; high timing because the practice is continuing.
6.1	Recreational activities	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	The threat is considered negligible. Some recreational activities may cause local extirpations of nests; although across the subspecies' range this threat is likely minor overall.
6.2	War, civil unrest & military exercises					N/A
6.3	Work & other activities					N/A
7	Natural system modifications					N/A
7.1	Fire & fire suppression					N/A
7.2	Dams & water management/use					N/A
7.3	Other ecosystem modifications					N/A
8	Invasive & other problematic species & genes	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Small scope because the spread of invasive species is primarily within the urban and agricultural areas of Canada. The natural habitats do not appear to have non-native bees present. Pathogen spillover and impacts remain unstudied in much of the ssp. range. Extreme severity because these practices impact bees. High timing because these practices are continuing.

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	The introduction and use of Common Eastern Bumble Bee for greenhouse pollination services in western Canada may further impact wild populations of Western Bumble Bee. Escaped and established populations of the Common Eastern Bumble Bee may out-compete native bumble bees for nesting habitat and/or floral resources, and introduced colonies may serve as a pathogen or disease vector. The status of establishment of wild populations of Common Eastern Bumble Bee in western Canada is unknown, but is likely to have a negative impact on native bumble bee species, as has been documented in other parts of the world for other managed species (Williams and Osborne 2009). Lab studies have shown the parasite species *Crithidia bombi* and *Nosema bombi* (suspected) have devastating effect on *Bombus* colony-founding queens, foraging workers and entire nests (Brown *et al.* 2000, 2003; Otterstatter *et al.* 2005).
8.2	Problematic native species					N/A
8.3	Introduced genetic material					N/A
9	Pollution	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	Small scope because there are large areas of natural habitat where the pesticide is not applied; serious severity because of the known impacts of pesticides, and high timing because the practice is continuing.
9.1	Household sewage & urban waste water					N/A
9.2	Industrial & military effluents					N/A
9.3	Agricultural & forestry effluents	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	Neonicotinoids pose a particular threat to bees (compared to other pesticides) because they are harmful even at concentrations in the parts per billion (ppb) (Environmental Protection Agency [EPA] 1994; Marletto *et al.* 2003). These pesticides are systemic and travel throughout the plant, reaching pollen and nectar.
9.4	Garbage & solid waste					N/A
9.5	Air-borne pollutants					N/A
9.6	Excess energy					N/A
10	Geological events					N/A
10.1	Volcanoes					N/A

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
10.2	Earthquakes/tsunamis					N/A
10.3	Avalanches/landslides					N/A
11	Climate change & severe weather	Not calculated	Pervasive (71-100%)	Unknown	High (Continuing)	Pervasive scope because climate change is ongoing across the entire species' range. Unknown severity because impacts are unstudied at a large scale. High timing because the threat is continuing.
11.1	Habitat shifting & alteration					N/A
11.2	Droughts	Not calculated	Pervasive (71-100%)	Unknown	High (Continuing)	Climate change is another possible threat (Williams and Osborne 2009). Bumble bee species shown to have narrow climatic tolerances are more vulnerable to extrinsic threats (Williams *et al.* 2009). Climatic tolerances for Western Bumble Bee are not currently unknown.
11.3	Temperature extremes					N/A
11.4	Storms & flooding					N/A

Agriculture and Aquaculture (Threat 2)

Habitat loss as a result of agricultural intensification is ongoing throughout southern portions of subspecies *occidentalis* range in BC, AB and SK, which have some of the most highly urbanized/farmed regions in Canada. The increased reliance on intensive agriculture over the past few decades has resulted in decreased quality foraging habitat for bumble bees globally (e.g., Williams 1989; Kosior *et al.* 2007). Agricultural intensification is less and not perceived as a high threat for subspecies *mckayi*. The use of chemicals (e.g., pesticides) in agricultural areas adds an additional, potentially severe threat to all bees. This is discussed in the pollution section below (Threat 9).

Invasive and Other Problematic Species and Genes (Threat 8)

Pathogen spillover has been implicated in the significant declines of many animals (Morton *et al.* 2004; Power and Mitchell 2004) but is a poorly understood threat for bumble bees. Pathogen spillover occurs when pathogens spread from a heavily infected 'reservoir' host population to a sympatric 'non-reservoir' host population (Power and Mitchell 2004). The use of infected commercial bumble bees (Common Eastern Bumble Bee in Canada) for greenhouse pollination is known to cause pathogen spillover into populations of wild bumble bees foraging nearby (Colla *et al.* 2006; Otterstatter and Thomson 2008). In western Canada, greenhouses using managed bees are present mostly across southern BC and to a lesser extent in the Lacombe and Redcliff regions of AB. The parasite species involved (*Crithidia bombi*), or suspected to be involved (*Nosema bombi*), in spillover to wild *Bombus* have detrimental effects on colony-founding queens, foraging workers and entire nests (Brown *et al.* 2000, 2003; Otterstatter *et al.* 2005). These parasites are found in a variety of bumble bee species (Macfarlane 1974; Macfarlane *et al.* 1995; Colla *et al.* 2006), but their virulence in wild Western Bumble Bee remains unknown. Nonetheless, the increased use of bumble bees in greenhouse operations in recent decades has been implicated in the decline of members of the subgenus *Bombus*, including *B. affinis* and Western Bumble Bee (Thorpe and Shepherd 2005; NRC 2007; Evans *et al.* 2008).

Recent surveys in Alaska (Koch and Strange 2012) found *Nosema* infection in subspecies *mckayi* to be on par with to slightly higher than in populations of the subspecies *occidentalis* in the United States. Commercial bumble bee colonies are used less in the north, and high levels of *Nosema* may be reflective of natural host-parasite levels (Koch and Strange 2012), and may not be spillover from greenhouses.

The introduction and use of the highly successful Common Eastern Bumble Bee (*B. impatiens*) in western Canada for pollination services may further impact Western Bumble Bee populations. The importation of Common Eastern Bumble Bee to greenhouses in BC may be a potential competitor and threat to declining populations, since this species has appeared to escape greenhouses the wild (Ratti and Colla 2010). This species may out-compete Western Bumble Bee for nesting habitat or forage resources. It may also serve as a pathogen or disease source. The status of wild populations of this introduced eastern species in western Canada is unknown, but may have adverse impacts on native species, as has been documented elsewhere (Williams and Osborne 2009).

In highly agricultural landscapes it likely competes for nectar with the introduced and managed European Honey Bee (*Apis mellifera* L.). However, competition is difficult to quantify under natural conditions (Thomson 2006), so the impact in agricultural landscapes is unknown. Honeybees have been in North America for hundreds of years making it difficult to ascribe recent reductions in Western Bumble Bee to impacts of direct competition with honeybees.

Pollution (Threat 9)

9.3 Agricultural and forestry effluents

Pollution via agrochemicals (i.e.. pesticides) is known to have detrimental effects on bees and other beneficial insects (e.g., Whitehorn *et al.* 2012; Baron *et al.* 2014). Many agrochemicals are known to impact bees, though much attention in recent decades has implicated neonicotinoides as a major risk to pollinators (Marandin and Winston 2003; Laycock *et al.* 2012; Whitehorn *et al.* 2012). At the approximate time that declines of Western Bumble Bee and other bumble bees in this subgenus were first noted, a new Imidacloprid pesticide (a neonicotinoid) was registered for use in the US (1994) and Canada (1995) (Cox 2001; PMRA 2001). Neonicotinoids are systemic pesticides that travel and accumulate throughout the plant, including pollen and nectar. These pesticides are detrimental to bees (compared to other pesticides) at concentrations in the parts per billion (ppb) (EPA 1994; Marletto *et al.* 2003). Imidacloprid is non-lethal to bumble bees when used as directed (e.g., Tasei *et al.* 2001). However, studies of its effects on bumble bees only tested one species, *B. impatiens*, as the representative for all North American species (Gels *et al.* 2002; Morandin and Winston 2003). Further study showed neonicotinoids had negative impacts on a European bumble bee species in the same subgenus as Western Bumble Bee (Tasei *et al.* 2001). Various life history traits of Western Bumble Bee (such as large body size, early emergence, long colony cycle, etc.) may make it especially vulnerable to accumulation of pesticides in the colony.

The widespread use of neonicotinoid pesticides throughout the range of the both subspecies has not been quantified and therefore is speculative only. Neonicotinoids are commonly used on golf courses and agricultural lands (Sur and Stork 2003). Large treated areas used for golf courses may expose bumble bees to large quantities of pesticides in otherwise suitable habitat (Tanner and Gange 2004).

Climate Change and Severe Weather (Threat 11)

Climate change is another possible threat to bumble bees (Williams and Osborne 2009). Bumble bee species with narrow climatic tolerances are more vulnerable to extrinsic threats (Williams *et al.* 2009).

Limiting Factors

Bumble bees require a constant suite of floral resources throughout the growing season to support colony growth, and without these resources, emerging queen, worker and colony growth is limited. Abundant food resources throughout the colony growth period ensure that local populations will persist. Only mated queens overwinter, so lack of abundant early season floral resources will cause colonies to die, or newly emerged queens to disperse.

Bumble bees are haplodiploid organisms with complementary sex determination which makes them extremely susceptible to extinction when effective population sizes are small (Zayed and Packer 2005). This is due to the ‘diploid male extinction vortex’ (Zayed and Packer 2005). Sex in bees, and most other haplodiploids, is determined by genotype at a single “sex locus”: hemizygotes (haploids) are males, heterozygotes are female and homozygotes are diploid males. Diploid males are usually sterile. The number of sex alleles in a population determines the proportion of diploids that are male and is itself determined primarily by the effective size of the population. This means that as bumble bee population size decreases, the frequency of diploid males increases. As diploid males are attempts at female production, their increasing production in smaller populations increases the rate of population decline causing a special case of the extinction vortex: “the diploid male extinction vortex.” This special form of genetic load is the largest known (Hedrick *et al.* 2006). In practical terms, if a bee population decreases to a few reproducing individuals, it is certain to become extinct even under stable environmental conditions unless its number increases within a few generations.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

There are no federal or provincial laws that protect Western Bumble Bee, mitigate threats to this group or protect the species’ nest sites or habitat.

Some Canadian provinces are considering a legislated ban on neonicotinoid pesticides, which would mitigate this threat to bees (see Threats, Pollution). At present, none of the governments within the range of Western Bumble Bee have proposed legislation.

Non-Legal Status and Ranks

The provincial and territorial conservation status ranks, using NatureServe criteria, will be part of Wild Species 2015 (Hebert pers. comm. 2013). The Canada National Status Ranks (Canadian Endangered Species Conservation Council [CESCC 2011]) are: BC and AB - N3 (sensitive), YT and SK - N5 (undetermined). The global conservation status rank is GU (not ranked based on lack of information) (NatureServe2013). The Xerces Society for Invertebrate Conservation (2013) Red-list assessment is Imperiled. The IUCN Red list (2013): None; and the species has not been reviewed or listed under the USA - federal *Endangered Species Act*.

In a review of global bumble bee declines globally, Williams and Osborne (2009) assess Common Eastern Bumble Bee (including its western form Western Bumble Bee) as Endangered using IUCN criteria: “A2: >50% population reduction since 1995 (inferred), causes may not be reversible and may not yet have ceased, based on very few records of individuals in the last four years, at least in the southwestern quarter of its range”.

The decline of Western Bumble Bee, and other members of the subgenus *Bombus s. str.,* appears to have started in the mid-1990s (NRC 2007). *Bombus franklini* has disappeared from its range in western USA and is listed by the IUCN as critically endangered (Evan *et al.* 2008). *Bombus affinis* has recently been assessed as Endangered by COSEWIC in Canada. *Bombus terricola* also appears to have declined (NRC 2007, Evans *et al.* 2008). These declines have not yet been attributed to any one cause (NRC 2007, Evans *et al.* 2008).

Habitat Protection and Ownership

There has not been an analysis that determines land ownership status across the species' range. Much of land within the populated areas adjacent to the international border is privately owned, urban and/or managed intensively for agricultural purposes.

The Canadian range of Western Bumble Bee spans numerous provincial and national parks and protected areas. Recent (since 2003) records from protected areas include:

British Columbia: Subspecies *occidentalis* has been recorded from local government parks: Boundary Bay Regional Park (2010, Metro Vancouver), Mount Douglas Park (2012, Saanich), Mount Tolmie Park (2012, Saanich), Christmas Hill Nature Sanctuary (2012, Saanich), Highrock (Cairn) Park (2012, Esquimalt), Brentwood Bay (Gardens) (2012, Central Saanich). Provincial parks include Manning Provincial Park and federal parks include Mount Revelstoke National Park and Yoho National Park. In 2013 surveys included provincial parks within the range of subspecies *mckayi* although data has not yet been analyzed (Sheffield pers. comm. 2013).

Alberta: Subspecies *occidentalis* has been recorded in Cypress Hills Inter-provincial Park (AB-SK), Banff National Park, Dinosaur Provincial Park.

Saskatchewan: Subspecies *occidentalis* has been recorded in Cypress Hills Inter-provincial Park (AB-SK), Grasslands National Park

Northwest Territories: Subspecies *mckayi* has been recorded in Nahanni National Park Reserve, Naats'ihch'oh National Park Reserve.

Yukon: No records from parks or protected areas, although subspecies *mckayi* likely occurs in these areas.

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Cover photograph by David Inouye, Western Bumble Bee worker robbing an *Ipomopsis* flower.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Sheila R. Colla has studied various aspects of bumble bee ecology and behaviour throughout North America. Previously she worked as a research assistant to Dr. James Thomson, Dr. Michael Otterstatter, and Dr. Robert Gegear at the University of Toronto, St. George Campus looking at pathogen spillover from managed to wild bumble bee populations. She is currently a doctorate student and recipient of the NSERC Alexander Graham Bell Canadian Graduate Scholarship at York University, Toronto, ON under the supervision of Dr. Laurence Packer. Her dissertation examines changes in bumble bee communities over the past century and looks into some of the causes for observed declines. In addition, she is a member of the North American Pollinator Protection Campaign and her research has been featured in *The Washington Post*, *Canadian Gardening*, *The Toronto Star, BioScience,* CBC's *Quirks and Quarks*, and *The Daily Planet* for Discovery Channel Canada.

Michael C. Otterstatter has worked on bumble bees and their parasites since 1997. This work has been done in conjunction with noteworthy bumble bee researchers, including Robin Owen, Lawrence Harder, James Thomson, Robert Gegear, and Sheila Colla. Michael has done several studies on the bumble bees of Alberta, with particular attention to parasitic flies and mites (MSc work), and on the bumble bees of southern Ontario, with particular attention to parasitic protozoa and the spillover of disease from commercial to wild populations (PhD work). This latter work has been featured in *New Scientist*, *Scientific American*, and the *New York Times*. Additional studies have included an investigation of the natural enemies of bumble bees in southern Chile. Michael currently works as an epidemiologist and pursues projects in bumble bee conservation with a variety of collaborators.

Leif L. Richardson is a PhD candidate at Dartmouth College, Hanover, NH, where he examines the effects of floral nectar chemistry on bees and their parasites. Additionally, he combines bee surveys with museum collections data to study changes in the distribution of North American bumble bees. With Sheila R. Colla and other co-authors he produced a Guide to the Bumble Bees of North America, to be published by Princeton University Press in 2014.

Cory S. Sheffield has been studying bees and pollination since 1993, as part of undergraduate honours studies at Acadia University, Wolfville, NS. He continued graduate studies (MSc) of insect-plant interactions at Acadia, and at Agriculture and Agri-Food Canada (AAFC), Kentville, NS from 1994 - 2006. Cory did graduate studies (PhD) at the University of Guelph, ON while continuing to work at the AAFC. These studies focused on the bee fauna of Nova Scotia, including their diversity and contributions to crop pollination. During this time, Cory and several co-authors published on the re-discovery of *Epeoloides pilosulus* in Nova Scotia, which was thought extinct. Cory then worked on post-doctoral studies at York University, ON in bee taxonomy and DNA barcoding, followed by a research associate position in bee taxonomy with the Canadian Pollination Initiative (CANPOLIN). He is now research scientist and curator of invertebrate zoology at the Royal Saskatchewan Museum in Regina, SK. His research continues to focus on bees: he has published on the taxonomy of Canadian/North American bees, the utility of DNA barcoding for bees, bee physiology, pollination contributions and diversity of the Canadian bee fauna.

COLLECTIONS EXAMINED

Data from numerous North American collections were used for analysis presented in this report. More than 70 individuals and institutions contributed to the dataset, and are listed at: www.leifrichardson.org/bbna.html.