COSEWIC
Assessment and Status Report

on the

Rusty-patched Bumble Bee
Bombus affinis

in Canada

ENDANGERED
2010

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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COSEWIC
Assessment Summary

Assessment Summary – April 2010

Common name
Rusty-patched Bumble Bee

Scientific name
Bombus affinis

Status
Endangered

Reason for designation
This species, which has a distinctive colour pattern, was once commonly found throughout southern Ontario. Active searches throughout its Canadian range have detected only one small population over the past seven years which suggests a decline of at least 99% over the past 30 years. It is threatened by disease, pesticides, and habitat fragmentation, each of which could cause extirpation in the near future.

Occurrence
Ontario, Quebec

Status history
Designated Endangered in April 2010.

COSEWIC
Executive Summary

Rusty-patched Bumble Bee
Bombus affinis

Species information

The Rusty-patched Bumble Bee (bourdon à tache rousse) (*Bombus affinis*) is one of five North American members of the subgenus *Bombus*. It is a medium to large-sized bumble bee with several distinguishing characters. Males and workers have a second abdominal segment that is half reddish-brown and half yellow. Queens can be difficult to distinguish from some other species.

Distribution

This species ranges from southern Ontario and southwestern Quebec in the north, south to Georgia and west to the Dakotas. In the southern parts of its range it occurs primarily at high elevations.

Habitat

The Rusty-patched Bumble Bee has been recorded from diverse habitats including mixed farmland, sand dunes, marshes, urban and wooded areas. It has been recorded feeding from a variety of plant genera for pollen and nectar. It usually nests underground in abandoned rodent burrows.

Biology

This species, like all bumble bees, has an annual life cycle. Mated queens emerge from diapause in the spring and look for potential nest sites. The queen then forages and lays eggs to produce a brood of workers. Workers hatch and take over nest care and foraging. Towards late summer, males and new queens are produced. These reproductive individuals leave the colony and mate. Mated new queens go into hibernation while all other castes perish. Like other bumble bees, Rusty-patched Bumble Bee individuals have warning colouration and females will sting when touched.

Population sizes and trends

In the 1970s, the Rusty-patched Bumble Bee was relatively common compared to other bumble bee species. Dramatic declines were noticed by the mid-1990s in Canada and in the USA. In Canada, only three specimens were observed (one in 2005 and two in 2009) despite extensive targeted searches from 2005-2009.

Limiting factors and threats

The reason for the sudden decline of this previously common species throughout its large range is unknown. It has been hypothesized that the species suffered from introduced diseases from managed bumble bees used for greenhouse pollination. Additionally, habitat loss and the widespread use of a new group of pesticides likely pose substantial threats.

Special significance of the species

The Rusty-patched Bumble Bee is in flight for a longer period than are most other Bumble Bees and it visits numerous plant genera in many habitat types. Thus, it is likely an important pollinator of both agricultural crops and native flowering plants. The loss of this species may result in increased vulnerability of native mammals, birds and other organisms which rely on pollinated plants for food and shelter. This species has also been used in the past for scientific study as it is easily reared in captivity and has become an important reference species for research in physiology and sociobiology.

Existing protection

The Rusty-patched Bumble Bee is listed on the Xerces Society's red-list of pollinator insects as 'Imperiled'. No practical or legal protection exists in Canada or the USA.

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
(2010)

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

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SPECIES INFORMATION

Name and classification

Bombus affinis Cresson (1863) is a member of the well-known and economically important family Apidae, which includes, among others, all bumble and honey bees. The genus *Bombus* Latreille 1802 (=Bumble Bees) includes approximately 250 species found primarily in temperate regions of North America, Central America, South America, Europe and Asia. In North America, five species belong to the subgenus *Bombus sensu stricto* Latreille (*Bombus occidentalis, B. franklini* (critically endangered, IUCN), *B. terricola, B. affinis* and *B. moderatus)*.

Bombus affinis Cresson was first described by Cresson (1863). While the taxonomy of some bumble bee species is controversial, the status of *B. affinis* is not (Cameron *et al.* 2007).

The classification of this species is as follows:

Phylum Arthropoda,
- Class Insecta,
  - Subclass Pterygota,
    - Order Hymenoptera,
      - Suborder Apocrita,
        - Infraorder Aculeata,
          - Superfamily Apoidea,
            - Family Apidae,
              - Subfamily Apinae
                - Genus *Bombus*,
                  - Subgenus *Bombus*
                    - Species *B. affinis.*

Common names include the Rusty-patched Bumble Bee, Rusty-Tinged Bumble Bee and Affable Bumble Bee. In French it is called bourdon à tache rousse.

Morphological description

Workers and males are medium-sized (1-1.6 cm in length) with variable abdominal colouration ranging from T1 and T2 segments (the first of which is actually fused to the thorax and the second of which is the first segment of the apparent abdomen called tergum 1, or T1) all brown to T1 being yellow and T2 half brown and half yellow (Laverty and Harder 1988) with the latter combination being the most common (Figures 1 and 2). Queens are large (~2 cm in length) with yellow pile on the thorax and first two abdominal terga (Figure 3). The remaining abdominal segments are completely black. Near Boston, Mass., U.S.A., another colour morph (var. *novae-angliae*) has been described where males and workers have reddish pile on the third, fourth, fifth or sixth segments as well (Bequaert 1920). For all castes, the pile on top of the head and on the face is black, and on the thorax mostly yellow, except for the presence of black pile between the wing bases. None of the other members of this subgenus has these colour patterns. In all castes, the head is broadly rounded with the space between the base of the mandible and the compound eye about 2/3 as long as wide in queens and workers, and slightly wider than long in males (Laverty and Harder 1988). Relative to other bumble bee species, all castes of this species have a short tongue length (Laverty and Harder 1988).

Figure 1. Photograph of female worker specimen collected at Pinery Provincial Park, Ontario, 2009 (Photo by S. Colla, York University). No good quality images of living Canadian specimens are known for any sex or caste.

Figure 2. Photograph of male specimen collected at Pinery Provincial Park, Ontario, 2005 (Photo by C. Ratti, York University).

Figure 3. Photo of *Bombus affinis* queen (by S. Colla, York University). Specimen collected in 1971 at 1000 islands, Ontario. Note the lack of brown colouration on the second abdominal segment unlike the worker and male.

Genetic description

There have been no studies of the genetic structure of *Bombus affinis* populations. Cameron *et al*. (2007) used a specimen of *B. affinis* from Illinois for their comprehensive phylogeny of bumble bees. A male specimen collected at Pinery Provincial Park in 2005 was sequenced and submitted to the Barcode of Life Data Systems; the sequence will be available shortly on GenBank.

Bombus affinis is a haplodiploid organism with complementary sex determination (see Limiting Factors for further discussion with regards to this genetic system and extinction risk).

There is no reason to consider this species as representing more than one designatable unit.

DISTRIBUTION

Global range

Bombus affinis has been recorded across Eastern North America from the Dakotas in the west, to Ontario and Quebec in the north and south to Georgia (Figure 4; Milliron 1971).

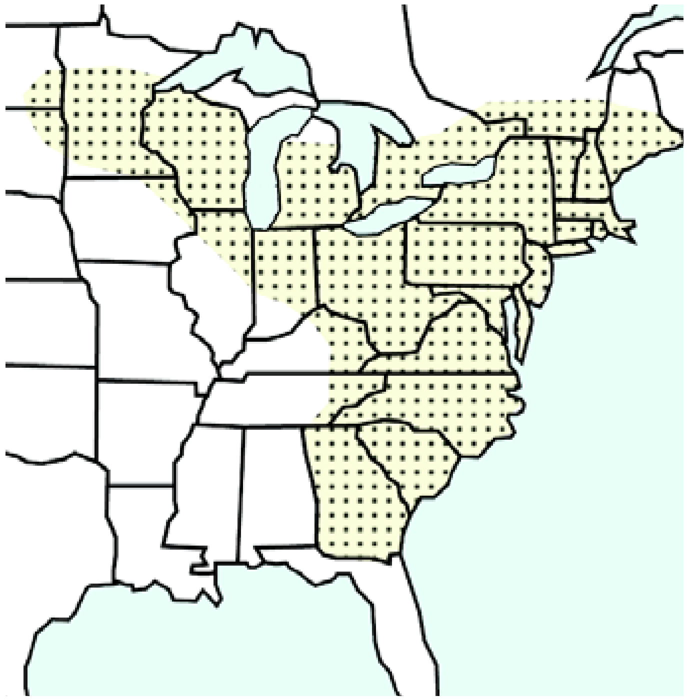


Figure 4. Historic distribution of *Bombus affinis*. Map is based on *A Monograph of the Western Hemisphere Bumblebees* by Milliron (1971) as presented in Evans *et al*. (2008). Note that in the southern portion of the species' range it occurs only at high altitudes.

During the summers of 2005-2007, 25 sites were surveyed for *B. affinis* throughout its U.S. range (Colla and Packer 2008). Seventeen of these sites were chosen based on previous records of *B. affinis* in various insect collections. Other sites were chosen within the species' historic range. Using randomization software (Zayed and Grixti 2005), it was determined that by collecting 150 individual bumble bees at each site, there would be a less than 5% chance of missing *B. affinis* if it was present at historical abundances. To increase the chances of detection, 200 individuals were collected, identified and released at each site and the presence/absence of the species determined. Not a single *B. affinis* was collected at any of the surveyed sites (Fig. 5).

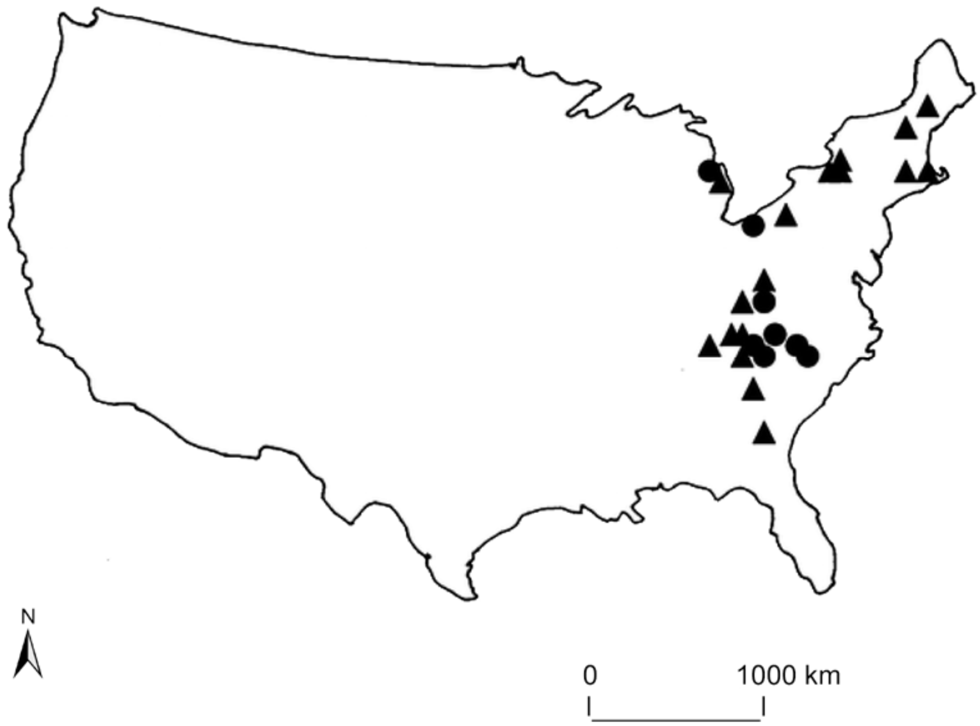


Figure 5. Historical (prior to 2000) (triangles) and additional (circles) sites sampled during the summer of 2006 for the presence or absence of *Bombus affinis* throughout its eastern U.S. range. No individuals of this species were found (from Colla and Packer 2008).

Canadian range

In the Bumble Bees of Eastern Canada (Laverty and Harder 1988), the species' range in Canada is stated to be restricted to southern Ontario and southwestern Quebec. The collections surveyed for that publication and for this report did not yield a single specimen from any province other than QC and ON. In 'Bees of the Eastern United States' (Mitchell, 1962), it is stated that *Bombus affinis* occurs in three Canadian provinces (ON, QC, NB). The collection at Cornell University has specimens of *B. affinis* from New Brunswick county in New Jersey. This is likely an error and in the absence of any confirmed specimens from the Maritimes, it is assumed for this report that the range published in Laverty and Harder (1988) is correct. Figures 6 and 7 show southern Ontario divided into 100 x 100 km grid cells. Fifteen grid cells where *B. affinis* had been recorded historically (Fig. 6) were searched in 2005-2008. Previous studies have used grid cells to document range decline in bumble bees (Williams 1982; Fitzpatrick *et al*. 2007). During the recent survey, *B. affinis* occurred only in one grid cell at Pinery Park, in 2005, and was not seen there from 2006-2008 despite directed searches (see Search Effort). Two individuals were found in the park in August 2009. Additional sites (not included in Fig. 6) where the species has been collected in Quebec (historically in the late 1970s) include Longueuil, Saint-Pie, Granby, Saint-Hyacinthe (la Collection André-Francoeur à Saguenay, M. Savard, Pers. Comm.), but these specimens have not been verified by the report writer.

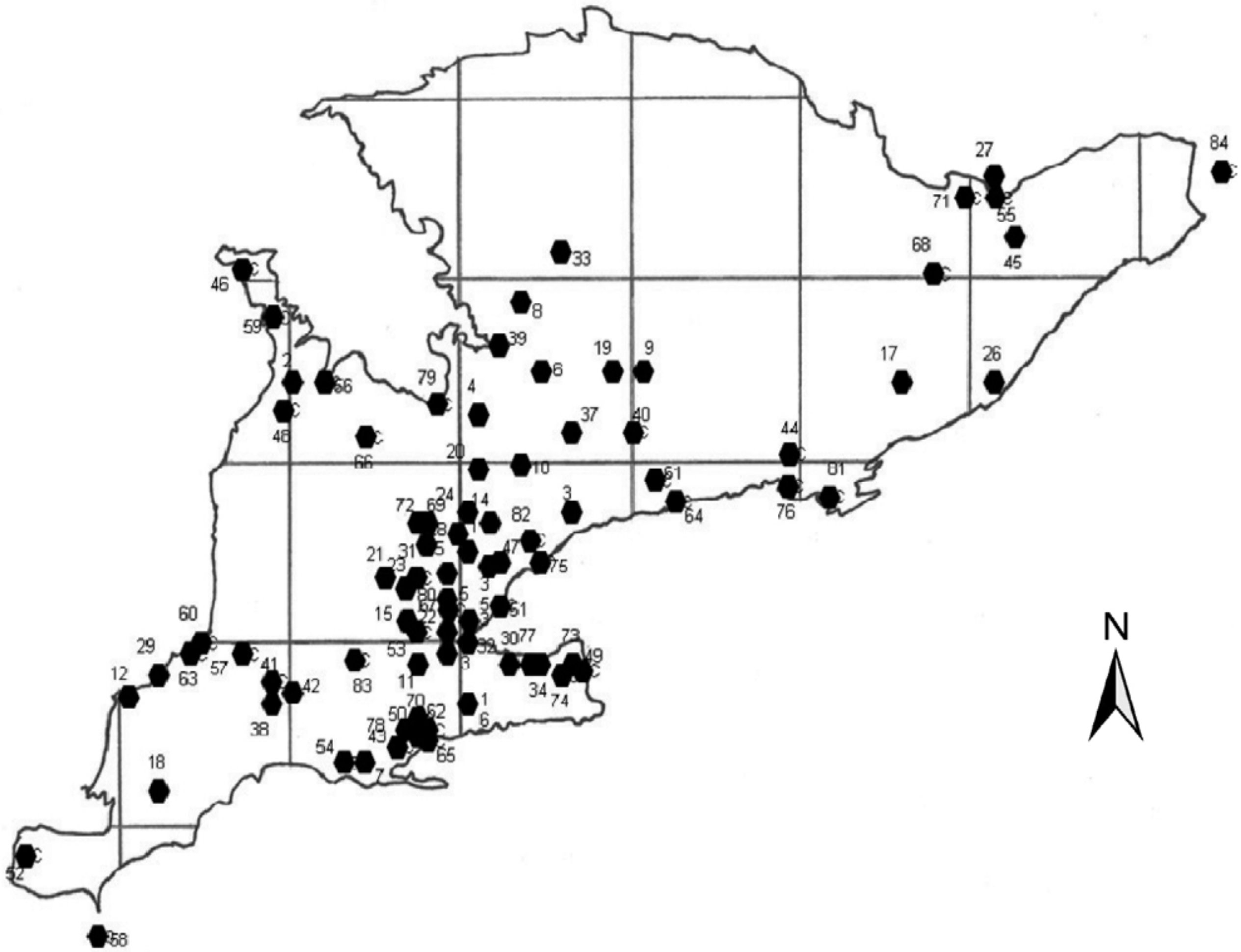
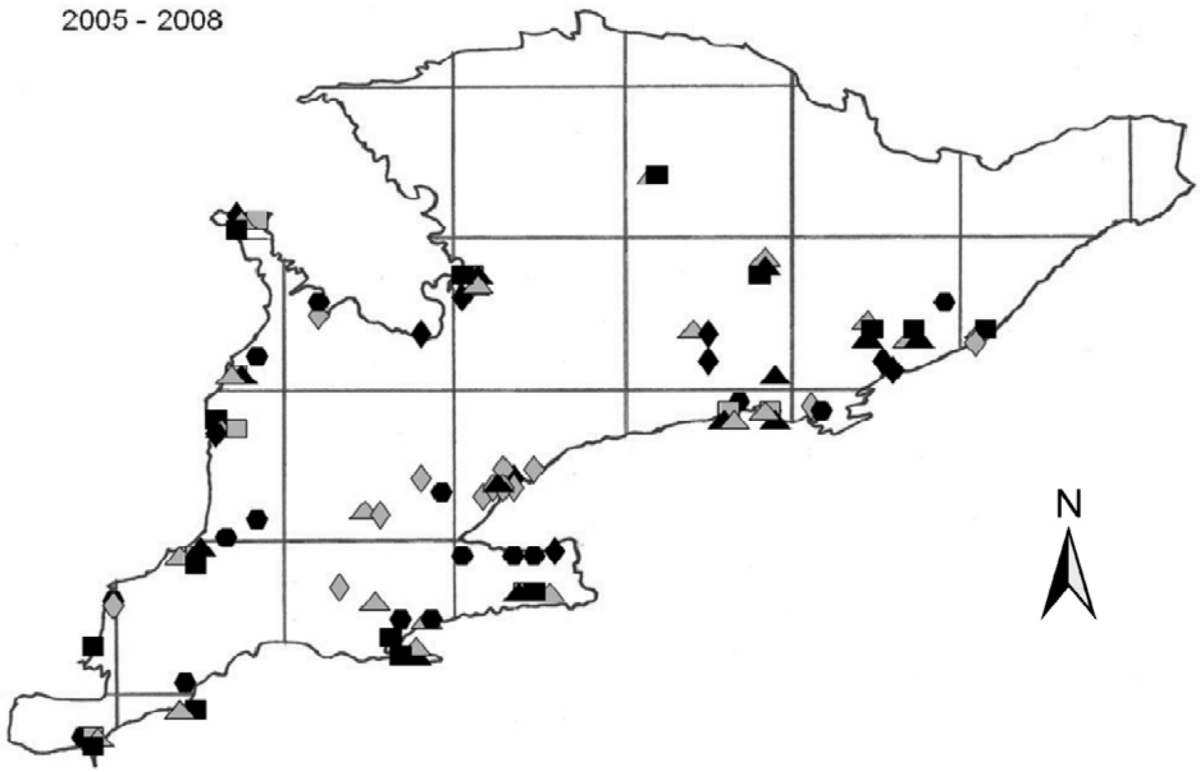


Figure 6. *Bombus affinis* records from 1899 to 2000 [includes databased specimens from examined collections, the Canadian National Collection online records and Milliron (1971)]. In Quebec the species has been confirmed from Gatineau and Montréal. Figure divided into 100 x 100 km grid cells. See Appendix 2 for list of numbered sites.



Symbols: Urban garden Urban Park Agricultural field
Sand dune/Beach Marsh/Bog Forest Old Field/Meadow

Figure 7. Sites surveyed for *Bombus affinis* by S. Colla (From Colla and Packer, in prep) from 2005-2008. Figure divided into 100 x 100 km grid cells.

For the purposes of this report, the historical Canadian range for this species does not include New Brunswick despite the distribution data suggested by Mitchell (1962). There are numerous reasons for excluding this province. Steve Javorek (Agriculture and Agri-Food Canada) recently compiled bumble bee community data from the Maritime Provinces from the past 15 years and did not come across a single *Bombus affinis* specimen (Javorek pers. comm Nov. 2008). None of the collections examined for this report, including the Canadian National Collection, had any specimens from New Brunswick (Fig. 6). Sites were surveyed in June 2008 by S. Colla in southern and central New Brunswick for the purposes of this report, without any specimens of the species being detected. These sites were: Fredericton, Alma, Bay of Fundy National Park, Hopewell Cape, and Moncton. Entomologist Dr. Paul Williams of the Natural History Museum in London, England is the world authority on bumble bees and he does not have any records of *B. affinis* northeast of Maine (Williams pers. Comm.. Nov. 2008). Lastly, there are numerous studies published on the historical range of *B. affinis* which include only ON and QC in Canada (Milliron 1971; Laverty and Harder 1988; Evans *et al*. 2008). In conclusion, Mitchell (1962) likely gave the province of New Brunswick in error and the specimens he was referring to are likely from New Brunswick county in New Jersey, USA.

HABITAT

Habitat requirements

Bombus affinis is a generalist species. It requires a temperate climate and is restricted to regions south of the boreal forest. Compared to some other bumble bees, *B. affinis* seems to be relatively cold-tolerant and has been found at elevations as high as 1676 m in the southern parts of its range (Canadian National Collection).

Nesting Habitat**:** Based on records from the U.S. and Canada, over 90% of *B. affinis* nests have been found underground, usually in old rodent burrows (Macfarlane 1974; Laverty and Harder 1988). Occasionally, *B. affinis* nests are found above ground, in one incidence inside an abandoned armchair (Macfarlane 1974). Nests of this species are likely similar to other bumble bee species but are extremely difficult to locate in the wild (Harder 1986). Brood cells and honey pots are made of wax produced by the queen and workers.

Foraging Habitat: This species has been found foraging in a wide variety of habitats such as mixed farmland, sand dunes, marshes, urban and wooded areas. As the species is active from April to October a lengthy period of abundant flowering plants is required. Please see Appendix 1 for a list of recorded forage plant species.

Hibernating Habitat: There are no data on overwintering habitat for *B. affinis* but mated queens likely burrow underground, or in rotting logs as do queens of other *Bombus* species (Macfarlane 1974).

Habitat trends

The majority of the species' Canadian range occurs in southern Ontario with the remainder found in extreme SW Quebec. Southern Ontario is the most densely populated region in Canada and thus has much urban sprawl. Southern Ontario and Quebec also have a large percentage of land used for intensive agriculture. Globally intensive agriculture has shifted to relying on chemical fertilizers rather than traditional nitrogen-fixing plants (Matson *et al*. 1997). Nitrogen-fixing plants (e.g., clovers, alfalfa etc.) are rich in pollen and nectar and likely provide important forage habitat in agricultural areas. In the U.K., bumble bee declines have been attributed to the increasing lack of available forage in agricultural landscapes (e.g., Williams 1986; Goulson *et al*. 2005). Habitat trends specifically relating to this species in Canada are unknown.

Habitat protection/ownership

Several suitable areas of *B. affinis* habitat are within protected areas. The most recently collected specimen was found in Pinery Provincial Park in Ontario, Canada. In the U.S., bumble bees have been surveyed in the past 10 years at Patuxent National Wildlife Refuge in Maryland by Sam Droege, and the Great Smoky Mountains National Park by Adrian Mayor. Specimens of this species have not been collected in either protected area since 2002 and 2000 respectively (Evans *et al*. 2008).

BIOLOGY

The following information is compiled from various references on general bumble bee biology (Alford, 1975; Laverty and Harder 1988; Goulson 2003; Benton 2006). Where applicable, references are provided for information pertaining to *B. affinis* specifically.

Life cycle and reproduction

Bombus affinis is a typical primitively eusocial (i.e., it has queen and worker castes where the workers are the offspring of the queen) bumble bee with annual colonies (i.e., one year = one generation). Mated queens emerge from hibernation in the spring after overwintering and begin feeding. Spring queens search for a suitable nest site where they then begin their colonies. A few weeks after the queen's initial egg-laying, female workers emerge and begin foraging for the colony and feeding the brood. As the 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 males and the rest of the colony decline as fall approaches until they die in the winter. The largest colony recorded produced 2,100 individuals in captivity (MacFarlane 1974) but in the wild, colonies are likely much smaller. Very little is known about mating behaviour and colony dynamics in *B. affinis*. In a closely-related species, *B. terrestris*, females mate with a single male during a single mating event and the sperm is stored in a spermatheca until used in fertilization (Greeff and Schmid-Hempel 2008).

Eggs hatch after approximately four days and the small larvae begins to feed on pollen and nectar. The larval stage of bumble bees has four instars. After almost two weeks of development, the larvae spin cocoons and pupate. Pupae develop for another two weeks before hatching as full-sized adults. In total, development takes approximately five weeks but this varies with temperature and food supply (Alford 1975). *Bombus affinis* is a 'pollen-storer' meaning the larvae live in cells and are fed individually by adults opening the brood clump 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.

Phenology

Bombus affinis is one of the earliest bees to emerge in the spring and one of the latest to cease foraging in the fall (Lui 1973; Macfarlane 1974). According to data obtained from museum specimens (see collections examined), queens emerge sometime after mid-April and can continue to forage until the end of July. Workers have been collected foraging from mid-May until the end of September. In Guelph, ON, peak worker production was found to be during the middle two weeks of June (Lui 1973). Males have been collected from as early as mid-May to the end of October and new queens, from mid-August to late September (Lui 1973). The timing of the colony cycle can vary year to year with seasonal variation and latitude.

Natural enemies

Like other sympatric bumble bees, *B. affinis* suffers from social parasites, where females enter the colony, kill the queen and lay eggs cared for by the remaining workers. *Bombus (Psithyrus) ashtoni* in particular specializes on usurping queens of *B. affinis* and the closely-related *B. terricola*. *Bombus ashtoni* is a naturally occurring social parasite which has not been seen anywhere for approximately 10 years, and is unlikely to have been a factor in the decline of *B. affinis*.

Microscopic endoparasites recorded infecting *B. affinis* include *Sphaeruluria bombi* (a nematode infecting 10% of overwintered queens) and *Apicystis bombi* (Neogregarinida: Ophrocystidae) (Macfarlane 1974; Macfarlane *et al*. 1995). Other parasites that are known to infect sympatric species are *Nosema bombi* (Microsporidia: Nosematidae) and *Crithidia bombi* (Kinetoplastea: Trypanosomatidae) (Colla *et al*. 2006) but these have not been recorded in *B. affinis* (possibly because of their recent introduction from Europe and the rarity of *B. affinis* in recent years).

Macroparasites of sympatric species include conopid flies and *Locustacarus buchneri* (a tracheal mite) (Macfarlane *et al*. 1995). Predators include robber flies and crab spiders (S. Colla, pers. obs.). Raccoons, skunks and other mammals have also been known to eat bumble bee colonies (Breed *et al*. 2004).

Physiology

Bumble bees have the rare physiological capability (among insects) to thermoregulate (Heinrich 2004). They are able to generate heat in their thoracic muscles, by shivering, to reach the required minimum temperature for flight (approx. 30°C) (Heinrich 2004). Given that bumble bees fly in the spring and fall in temperate regions, this internal temperature can be well above ambient temperature. Since *B. affinis* is one of the earliest spring emerging species, such thermoregulation is likely an extremely important adaptation.

Dispersal

There is no information specifically for *B. affinis* and little for bumble bees as a group on this subject. Nevertheless, given the patchiness of good quality 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), dispersal is likely important to survival. The opportunity for dispersal occurs with the movement of reproductive individuals, primarily queens in spring that disperse while searching for suitable nest sites (Goulson 2003). There is some evidence that bumble bees are able to disperse relatively long distances. Males of a closely related species (*B. terrestris*) have been estimated to fly between 2.6 and 9.9 km from the colony of origin (Kraus *et al*. 2008). Additionally, *B. terrestris* 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). Passive dispersal of *B. affinis* by anthropogenic or other means is unlikely.

Interspecific interactions

Because *B. affinis* is a generalist forager, it competes with many other bee species for food resources. In particular, because of similar tongue lengths, *B. affinis* likely competes for nectar with the introduced honey bee: *Apis mellifera*. However, competition is extremely difficult to study in natural conditions (Thomson 2006) and because honey bees have been in North America for hundreds of years, it is difficult to ascribe recent reductions in *B. affinis* to impacts of direct competition with honey bees.

Native bumble bees which may be possible competitors of *B. affinis* include *B. impatiens, B. bimaculatus, B. rufocinctus, B. griseocollis.* These species have short to medium tongue lengths and seem to have increased in abundance or range in recent decades (Colla and Packer 2008). *Bombus impatiens* in particular has increased in numbers substantially in urban areas (Colla and Packer, in prep.), has expanded its range (Sheffield *et al*. 2003) and is increasingly managed for greenhouse and field crop pollination (e.g., Shipp *et al*. 1994).

Bombus affinis likely has important mutualisms with early spring flowering plant species which may rely on it for pollination. These plants are likely among those included in Appendix 1 but other, unrecorded host plant species, may also be negatively impacted by declines in *B. affinis* populations. The extent of interdependence of individual plant species with *B. affinis* is unknown.

Adaptability

The survival of *B. affinis* in spring and fall in temperate climates is aided by their relatively large body size and dense pile. Their physiological ability to thermoregulate to temperatures above ambient temperatures allows them to adapt to the colder climates at the northern edge of their range. Behavioural modifications (such as ceasing foraging mid-day in hot weather and fanning of the colony) also aid in temperature regulation.

The female stinging apparatus and warning colouration provide protection against some predators and humans.

Members of the subgenus *Bombus* have evolved a behavioural adaptation known as ‘nectar-robbing’. Although these members have relatively short tongues, they pierce the corollas of floral nectar tubes to access nectar from long-tubed flowers. They can thus obtain nectar in the absence of floral hosts to which their tongue length is more closely adapted.

Bombus affinis has been reared in captivity relatively easily in the past for scientific study (R. Gegear and the late T. Laverty pers. comm., Macfarlane 1974).

POPULATION SIZES AND TRENDS

Search effort

Compared to most other insects, bumble bees are quite easily found and identified in the field. As a result, many studies have investigated various ecological and evolutionary mechanisms using *Bombus* as a model system, resulting in the documentation of the presence of *B. affinis* in various regions of the U.S. and Canada. Southern Ontario in particular has been the region where many studies of bumble bee ecology have been performed (e.g., Macfarlane 1975). However, until recently, very few surveys have been conducted to specifically determine the status of the species in the wild and to document changes in populations from year to year.

Colla and Packer (unpublished data) surveyed sites throughout southern Ontario to determine whether there have been changes in bumble bee communities over time compared to historical data (Fig. 7). Sites were surveyed in the summers from 2005-2008 for a minimum of 1 day but in some cases individual sites were surveyed for multiple days and years. More details on the sampling protocol can be found in Colla and Packer (2008). Despite sampling throughout the native Canadian range for *B. affinis*, only one specimen was found (Fig. 2). A male was collected in Pinery Provincial Park in August 2005. Each summer from 2006-2008, the park was surveyed for bees every 10 days from May to September and *B. affinis* individuals were not observed (A. Taylor, pers. comm.). S. Colla searched the park specifically for *B. affinis* for 2 days in August (when colonies are expected to be at their peak) each year from 2005-2009. From 2006-2008, not a single *B. affinis* individual was found. On August 21st 2009, two workers were found in the park, one on Spotted Knapweed and the other in a pan trap.

In total, over 600 hours of targeted search have been made for this species in Ontario since 2004 and thousands of hours of general bee survey work have been performed in areas previously inhabited by the species.

Abundance

Population sizes for Ontario and Quebec are unknown. In the past 10 years only three individuals have been collected in Canada despite active searching at historical sites.

Colla and Packer (2008) documented the decline in relative abundance of *B. affinis* after a 30-year period. Sites in Guelph and Belwood, Ontario were surveyed for bumble bees for three years (2004-2006) and the data compared to those from surveys performed in 1971-1973 at the same sites (Macfarlane 1974). In both studies, bumble bees were opportunistically collected using insect nets and identified to species. The studies differed in sampling intensity with Macfarlane (1974) sampling approximately every few days and Colla and Packer sampling once a week in 2006 and less frequently in 2004 and 2005. The study from 1971-1973 found that approximately 14% of the 3632 bumble bees collected were *B. affinis* making it the 3rd-4th most abundant bumble bee species. Using randomization software, it was determined that in order to detect *B. affinis* at the levels present in Macfarlane (1974), 150 bumble bees should be sampled at each site (at $P<0.05$ the chance of missing the species, if it was there, was less than 5%) (Colla and Packer 2008). From 2004-2006, a total of 1195 bumble bees were collected in the same sites (Speed River, Guelph and near Belwood Lake), none were *B. affinis*. This was the most dramatic decline of all the bumble bee species in the region (Fig. 8).

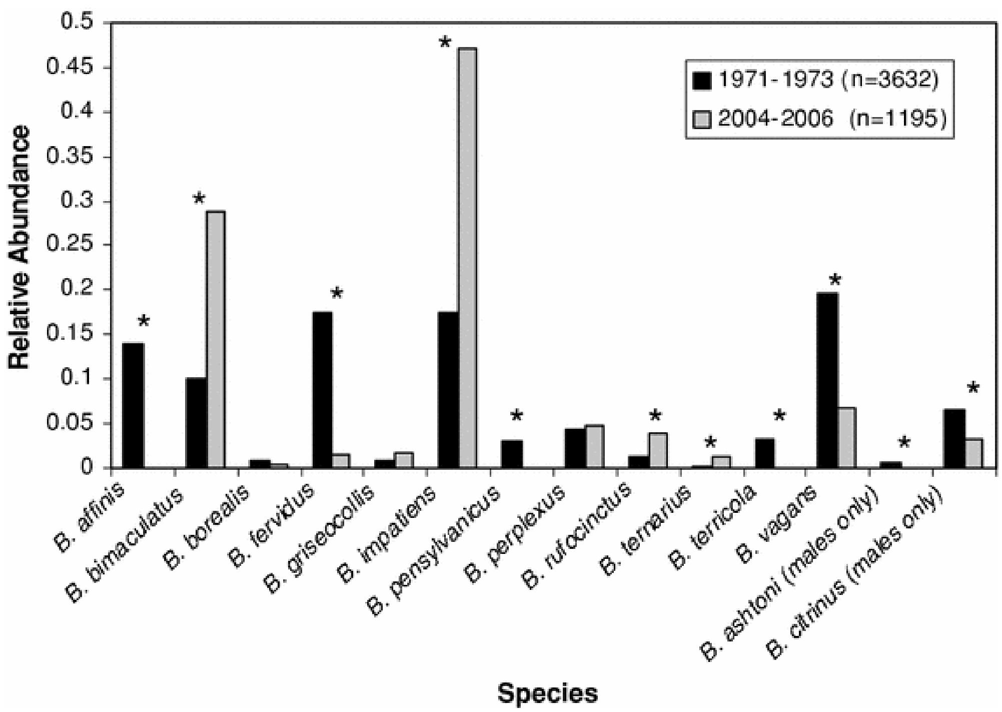


Figure 8. Comparison of the relative abundance of each bumble bee species collected in Southern Ontario from 1971–1973 (black) (Macfarlane 1974) and 2004–2006 (grey) (* indicates $P < 0.001$) (from Colla and Packer 2008).

There are difficulties associated with determining the abundance and/or effective population sizes of eusocial organisms. While abundance may be high at a given site, unless it is determined that all individuals are not from the same colony, the effective population size will be a tiny fraction of the number of individuals collected (Packer and Owen 2001; Darvill *et al*. 2004). The best measure of effective population size (in the absence of genetic data) is to survey queens (e.g., Kokuvo *et al*. 2008), but this may be detrimental to wild populations and difficult to accomplish as they are hard to find and emergence times differ from year to year.

Given the species' previously wide distribution in southern Ontario and just across the border in Quebec, its reduction to a single known site would indicate a reduction in EO, IAO and population size of at least two orders of magnitude.

Fluctuations and trends

Surveys have been carried out throughout the U.S. and Canadian range of *B. affinis* to determine whether populations have suffered the declines noted anecdotally. In all cases where adequate baseline data exist, *B. affinis* populations have suffered substantial declines (Colla and Packer 2008; Evans *et al*. 2008; Giles and Ascher 2006; Grixti *et al*. 2009). In recent decades, Canadian occurrences have declined (three individuals seen despite extensive searching) (see under Canadian range) and thus populations appear to have declined to the same extent.

In the U.S., there is also evidence for a declining trend in this species. Recent bee surveys from New York state, where *B. affinis* was once 'moderately abundant' (Leonard 1928), yielded no individuals despite a combined total of over 1460 collected bumble bees (Giles and Ascher 2006; Matteson *et al*. 2008). Grixti *et al*. (2009) used an electronic database and recent survey results to determine changes in the distribution and composition of bumble bees throughout Illinois. Based on data from 56 sites from 1900-1999 and 2000-2007, *B. affinis* declined in distribution by 33%. Additionally, 90% of the 50 *B. affinis* specimens collected during the latter time period were obtained from a single site.

Rescue effect

The rarity of this previously common species throughout its entire range in the U.S. (NRC 2007; Evans *et al*. 2008) would make recolonization of Canada highly unlikely. The only individuals documented in the U.S. in 2009 were in Daubenspeck Park, Indianapolis, Indiana, U.S.A. (Liz Day pers. comm.).

LIMITING FACTORS AND THREATS

Bombus affinis is at the most northern edge of its range in southern Ontario and SW Quebec. It is not known whether there is a physiological, behavioural or geographical barrier limiting its dispersal northwards. Climatic variables such as snow cover, precipitation, growing season length, etc., are likely important determinants of suitable habitat for bumble bees. Given the restriction of *B. affinis'* range to high elevations at the southern part of its range, it seems likely that this species is restricted to a narrow climatic niche. Williams *et al*. (2009) showed that bumble bees with narrow climatic niches are more vulnerable to extinction.

The rapid decline of *B. affinis* and other members of the subgenus *Bombus s.str.* seems to have commenced in the mid-1990s (NRC 2007). *Bombus franklini*, the species most closely related to *B. affinis,* has disappeared from its range in western USA and is listed by the IUCN as critically endangered (Evan *et al*. 2008). *Bombus terricola* and *B. occidentalis* have also declined throughout their ranges in Eastern and Western North America respectively (NRC 2007; Evans *et al*. 2008). These declines have not yet been attributed to any one cause, but based on the timing of the observed collapse, possible threats have been hypothesized (NRC 2007; Evans *et al*. 2008).

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 commercial bumble bees (*Bombus impatiens* in Canada) for greenhouse pollination with a high prevalence of parasites has been shown to cause pathogen spillover into populations of wild bumble bees foraging nearby (Colla *et al*. 2006; Otterstatter and Thomson 2008). Parasites found in commercial colonies have been found in species other than *B. impatiens* (Macfarlane 1974; Macfarlane *et al*. 1995; Colla *et al*. 2006) but the extent of their lethal and sublethal effects in other *Bombus* species 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 *B. terricola* (Thorp and Shepherd 2005; Berenbaum *et al*. 2007; Evans *et al*. 2008).

Around the time when the declines of *B. affinis* and other members of its subgenus were noted, a new pesticide (Imidacloprid, a neonicotinoid) was registered for use in the US and Canada (1994 and 1995 respectively: Cox 2001; PMRA 2001). Neonicotinoids have been shown to be especially lethal to bees (compared to other pesticides) even at concentrations in the parts per billion (ppb) range (EPA 1994; Marletto *et al*. 2003). Neonicotinoids are suspected of causing dramatic honey bee declines in Europe (resulting in their having been banned in some countries) and the U.S. (Schacker 2008; Williams 2008) and in having negative impacts on a bumble bee in the same subgenus as *B. affinis* (Tasei *et al*. 2001). The neonicotinoids are now commonly used in regions of eastern North America for crop, forest and turf pest control (Cox 2001). In Ontario, the amount of imidacloprid used in 2003 in agriculture was approximately 527 kg

(McGee *et al*. 2004; Brimble *et al*. 2005). The total quantity of imidacloprid used in Ontario is likely considerably larger if pet flea control, tree root drenches, greenhouse and turfgrass uses are included. These pesticides are systemic and travel throughout the plant, reaching pollen and nectar (Sur and Stork 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 species in Eastern North America (Gels *et al*. 2002; Morandin and Winston 2003). The lethal and sub-lethal effects of this group of pesticides urgently need to be determined for a wider range of species. Various life history traits of *B. affinis* (such as large body size, early emergence, long colony cycle, etc.) may make it especially vulnerable to accumulation of pesticides in the colony. Large areas used for golf courses may expose bumble bees to large quantities of pesticides in otherwise good habitat (Tanner and Gange 2004). A recent meta-analysis of environmental impacts upon bees has demonstrated that eusocial species are disproportionately affected by pesticides (Williams *et al*., submitted).

Another suspected threat to *Bombus affinis* populations is habitat loss. As mentioned above, bumble bees are more vulnerable to habitat fragmentation than other animal species for genetic reasons (Packer and Owen 2001). They also require large inputs of resources over a long period of time (April – October for *B. affinis*) as reproductives for the next generation are only produced towards the end of the colony cycle. 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). Additionally, southern ON and QC contain some of the most highly populated/urbanized regions of Canada. Suitable nesting, hibernating and foraging habitat is possibly difficult to find in these regions and is likely in short supply. Habitat loss is a steady long-term threat to this species, and likely does not explain its sudden collapse.

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 or inviable. 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 populations decrease in size, 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.

SPECIAL SIGNIFICANCE OF THE SPECIES

Bombus affinis is an important pollinator of native flowering plants and crops in North America. A thorough study of bumble bee floral host use indicated *B. affinis* visits at least 65 plant genera (Macfarlane 1974). In particular, it has been shown to be an excellent pollinator of cranberry (Cane and Schiffauer 2003), plum and apple (Medler and Carney 1963), alfalfa (Holm 1966), and onion (Caron *et al.* 1975). The long colony cycle of this species makes it likely to be the primary pollinator for many ecologically and economically important plants (including apple, raspberry, lilac, honeysuckle, hawthorn, nightshade, clover, milkweed, goldenrod and aster). Upon pollination, some of these plants provide fruits which sustain various avian and mammalian species among others. The loss of this bumble bee species may result in changes in food chains and ecosystem sustainability. Some of the noted visited plants for *B. affinis* also have important medicinal properties for First Nations people (e.g., *Aralia, Rosa, Rubus,* and *Spiraea*).

Bombus affinis is also ecologically important as it has one of the largest colony sizes ever recorded for a North American bumble bee species (Macfarlane 1974). Additionally, the social parasite bumble bee species *B. ashtoni* specializes on members of this subgenus (Laverty and Harder 1988), and has also suffered substantial declines in recent years (Evans *et al* 2008) probably as a consequence of host declines.

Because *Bombus affinis* is relatively easily reared in captivity and was historically quite common, it was used as a model system for various physiological and ecological experiments (e.g., Macior 1966; Fisher 1983; Bregazzi and Laverty 1992; Schiestl and Barrows 1999) and it is thus an important reference species for experimental biology and research.

Bumble bees are of special significance to First Nations people. Symbolically bumble bees have been depicted on totem poles, ceremonial masks, in artwork and legends. However, there is no known specific cultural significance for *B. affinis*.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Xerces Society of Invertebrate Conservation Red List Status: ‘Imperiled’ = “At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors”. The Xerces Society is a nonprofit organization which performs research and advocates for insect conservation. As a result their red-list does not provide any legal protection for the listed insects.

Canada-Species at Risk Act: None
Canada-Provincial Status: Ontario Natural Heritage Information Centre (OMNR) Rank: S1 Critically Imperiled
USA- *Endangered Species Act*: None
IUCN Red list: None

TECHNICAL SUMMARY

Bombus affinis
Rusty-patched Bumble Bee bourdon à tache rousse
Range of occurrence in Canada (province/territory/ocean): Ontario, Quebec

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used)	1 yr
Is there an inferred continuing decline in number of mature individuals?	Yes
Estimated percent of continuing decline in total number of mature individuals within either of 5 years or 2 generations	Unknown, could be 100%
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown, but averaged over the past 30 years the decline would likely have exceeded 30% per decade.
Suspected percent reduction in total number of mature individuals over the next 10 years.	100% is quite possible
Inferred percent reduction in total number of mature individuals over any 10 year period, over a time period including both the past and the future.	Not known with certainty but: minimum averaged over last three ten-year time periods 33% maximum >99%
Are the causes of the decline clearly reversible and understood and ceased?	Reversible – unlikely, understood - somewhat, ceased – no.
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence. Based upon existence of one known site.	4 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value; other values may also be listed if they are clearly indicated (e.g., 1x1 grid, biological AO)). Based upon existence of one known site.	4 km²
Is the total population severely fragmented?	In Canada, no – only one location. Globally, yes.
Number of "locations*"	1
Is there a projected continuing decline in extent of occurrence?	Yes, survival from one tiny population seems highly unlikely
Is there a projected continuing decline in index of area of occupancy?	Yes, survival from one tiny population seems highly unlikely
Is there a projected continuing decline in number of populations?	Yes, it is unlikely to survive from such a tiny population

*See definition of location.

Is there a projected continuing decline in number of locations?	Yes
Is there an inferred continuing decline in area, extent and quality of habitat?	Probably
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**
Pinery	Unknown but must be very small
Total	Unknown but must be very small

Quantitative Analysis

Probability of extinction in the wild is at least	Not performed

Threats (actual or imminent, to populations or habitats)

The one remaining known site in Canada is in Pinery Provincial Park. If the main cause of decline is disease then the chances of disease spreading to the park is high. If the cause is pesticide use, then pesticide drift is possible and would likely impact the species at any time from April to September. Given the small size of the remnant population, the genetic load caused by the unusual sex determining mechanism in bees is likely to result in extinction unless numbers increase considerably very quickly.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? **USA: Declining** Michigan, SC; Wisconsin, SU. Rare throughout range. On Xerces Society's Red List for At-Risk pollinators	
Is immigration known or possible?	Not known but highly unlikely
Would immigrants be adapted to survive in Canada?	Unlikely unless the cause of decline of the Canadian populations becomes known with certainty and removed
Is there sufficient habitat for immigrants in Canada?	Food and nest site resources yes, disease and pesticide-free space, apparently not
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (April 2010)

*See definition of location.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2ce; B1ab(i,ii,iv,v)+2ab(i,ii,iv,v)
Reasons for designation: This species, which has a distinctive colour pattern, was once commonly found throughout southern Ontario. Active searches throughout its Canadian range have detected only one small population over the past seven years which suggests a decline of at least 99% over the past 30 years. It is threatened by disease, pesticides, and habitat fragmentation, each of which could cause extirpation in the near future.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2ce. Both the abundance and area occupied have declined. The putative causes of decline (pathogens, pollutants, and fragmentation) have not ceased.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(i,ii,iv,v)+2ab(i,ii,iv,v). The EO and IAO are both 4km², the species has been found only at one site since 2000 despite repeated searches for it throughout its previous Canadian range, and continuing decline in EO, IAO, number of locations and number of individuals is expected based upon any of the putative threats. Decline in habitat is also probable.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. The total number of individuals remains unknown, although is certainly very small and probably less than the 2,500 threshold for endangered but this cannot be stated with certainty.
Criterion D (Very Small or Restricted Total Population): Not applicable. Total population is unknown.
Criterion E (Quantitative Analysis): Not performed.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

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.

COLLECTIONS EXAMINED

The following collections were consulted and all contain specimens of *Bombus affinis*:

Canadian Museum of Nature, PO Box 3443, Stn. D, Ottawa, ON, Canada K1P 6P4

Canadian National Collection 'Bombus of Canada Dataset' [Online records] http://data.gbif.org/datasets/resource/525 [Accessed December 2008]

Royal Ontario Museum, 100 Queen's Park, Toronto, Ottawa, ON, Canada M5S 2G6

University of Guelph Insect Collection, 1216 Edmund C. Bovey Building, University of Guelph, Guelph, ON, N1G 2W1

York University Bee Collection, Dept. of Biology, 4700 Keele St. Toronto, ON M3J 1P3

Appendix 1. List of forage plant species for *B. affinis* as compiled in Evans *et al*. (2008) and Milliron (1971).

Bombus affinis visits a wide variety of plants including *Abelia grandiflora*, *Aesculus* spp., *Asclepias syriaca*, *A. incarnata*, *A. verticillata*, *Aralia* spp., *Aster* spp., *Aquilegia canadensis*, *Aureolaria pedicularia*, *Berberis* spp., *Camassia scilloides*, *Carduus* sp., *Ceanothus americanus*, *Cercis canadensis*, *Chamaedaphne calyculata*, *Coreopsis major*, *Crataegus* spp., *Delphinium tricorne*, *Dicentra canadensis*, *D. cucullaria*, *Echium vulgare*, *Helianthus* spp., *Hydrangea* spp., *Hydrophyllum* spp., *Impatiens capensis*, *Lamium purpureum*, *Laportea* spp., *Leonurus* sp., *Linaria* sp., *Lonicera* spp., *Lotus corniculatus*, *Medicago sativa*, *Mertensia virginica*, *Monarda* sp., *Nepeta* spp., *Pedicularis canadensis*, *Pedicularis lanceolata*, *Philadelphus* spp., *Polymnia* spp., *Prunella vulgaris*, *Prunus* spp., *Pyrus ioensis*, *Pyrus malus*, *Rhododendron* spp., *Rhus* spp., *Ribes* spp., *Robinia* spp., *Rosa* spp., *Rubus* spp., *Salix* spp., *Solanum* sp., *Solidago* spp., *Symphytum officinale*, *Syringia* spp., *Syringia vulgaris* , *Taraxacum* spp., *Trifolium* spp., *Vaccinium* spp., *Verbascum* spp., *Verbesina occidentalis*, *Vicia* spp..

Additional food plant genera records published in Milliron (1971) are: *Angelica, Aster*, *Cirsium*, *Epilobium*, *Eupatorium*, *Lythrum*, *Malus*, *Spiraea*, *Veronica*, *Parnassia*, *Hypericum*, *Kalmia* and Rosa.

Appendix 2. Sites where *Bombus affinis* was found historically in Canada (Figure 6).

1	Acton
2	Allenford
3	Ancaster
4	Angus
5	Arkell
6	Atherley
7	Aylmer
8	Bala
9	Bobcaygeon
10	Bradford
11	Brantford
12	Bright's Grove
13	Burlington
14	Caledon
15	Cambridge
16	Cayuga
17	Chaffey's Locks
18	Chatham
19	Coboconk
20	Cookstown
21	Drayton
22	Dundas
23	Elmira
24	Forks of the Credit
25	Freelton
26	Gananoque
27	Gatineau Provincial Park
28	Georgetown
29	Pinery Provincial Park
30	Grimsby
31	Guelph
32	Hamilton
33	Huntsville
34	Jordan
35	Kelso
36	Kendal
37	Keswick
38	Komoka
39	Lake Matchedash
40	Lindsay
41	Lobo
42	London
43	Manester Tract, St. Williams

44 Marmora
45 Metcalfe
46 Miller Lake
47 Milton
48 Mt. Hope
49 Niagara Glen
50 Normandale
51 Oakville
52 Ojibway Prairie
53 Oliver Bog
54 Orwell
55 Ottawa
56 Owen Sound
57 Parkhill
58 Pelee Island
59 Pike Bay
60 Grand Bend
61 Pork Hill
62 Port Dover
63 Port Franks
64 Port Hope
65 Port Ryerse
66 Priceville
67 Puslinch Lake
68 Rock Dunder, Morton
69 Rockwood
70 Simcoe
71 S. March
72 Speedside
73 St. David's
74 St. John's west
75 Toronto
76 Trenton
77 Vineland Station
78 Vittoria
79 Wasaga Beach
80 Waterloo
81 Wellington
82 Woodbridge, Boyd Conservation Area
83 Woodstock
84 Montréal