

Status Review of Three Formerly Common Species of Bumble Bee in the Subgenus *Bombus*

Bombus affinis (the rusty patched bumble bee), *B. terricola* (the yellowbanded bumble bee), and *B. occidentalis* (the western bumble bee)



Photograph of *Bombus affinis* by Johanna James, 2008

Prepared by: Elaine Evans (The Xerces Society),
Dr. Robbin Thorp (U.C. Davis), Sarina Jepsen (The Xerces Society),
and Scott Hoffman Black (The Xerces Society)

TABLE OF CONTENTS

I. Executive Summary.....	3
II. Biology, Habitat Requirements, Pollination Ecology, and Taxonomy.....	4
A. Biology.....	4
B. Habitat requirements.....	6
C. Pollination Ecology.....	6
D. Taxonomy.....	6
III. The rusty patched bumble bee, <i>Bombus affinis</i> Cresson.....	7
A. Species Description.....	7
B. Pollination Ecology.....	8
C. Population Distribution and Status.....	9
IV. The yellowbanded bumble bee, <i>Bombus terricola</i> Kirby.....	13
A. Species Description.....	13
B. Pollination Ecology.....	14
C. Population Distribution and Status.....	14
V. The western bumble bee, <i>Bombus occidentalis</i> Greene.....	17
A. Species Description.....	17
B. Pollination Ecology.....	18
C. Population Distribution and Status.....	19
VI. Current and Potential Threats – Summary of Factors for Consideration.....	24
A. Spread of Diseases and Pests by Commercial Bumble Bee Producers... 24	
B. Inadequacy of Existing Regulatory Mechanisms.....	27
C. Habitat Alteration.....	28
D. Pesticides.....	29
E. Invasive Species.....	31
F. Other Threats.....	32
VII. Conclusion.....	33
VIII. Literature Cited.....	35
IX. Acknowledgements and Personal Communication.....	50
X. Appendix I.....	51
A. <i>Bombus affinis</i> Museum Records.....	52
B. <i>Bombus terricola</i> Museum Records.....	54
C. <i>Bombus occidentalis</i> Museum Records.....	55
XI. Appendix II.....	62

I. EXECUTIVE SUMMARY

Several years ago, bee biologists began to notice a reduction in the abundance and distribution of several bumble bee species, including three bumble bees that were formerly common, wide-spread and important pollinators of crops and wildflowers in North America: *Bombus affinis* (the rusty patched bumble bee), *Bombus terricola* (the yellowbanded bumble bee), and *Bombus occidentalis* (the western bumble bee).

The yellowbanded bumble bee and the rusty patched bumble bee were once widely distributed in northeastern and midwestern North America, and now are absent in most parts of their former ranges. The western bumble bee was formerly common and widespread throughout western North America. It can still be found in some areas in the northern and eastern parts of its historic range, but populations from southern British Columbia to central California have virtually disappeared.

Bumble bees are excellent pollinators of many crops and wild flowers. In the U.S., the economic value of pollination services provided by native insects (mostly bees, but not including the non-native honey bees) is estimated at \$3 billion per year (Losey and Vaughan 2006). In some crops, bumble bees pollinate more efficiently than honey bees on a bee to bee basis. Bumble bees are able to fly in cooler temperatures and lower light levels than many other bees, resulting in extended pollinating time. They also perform a behavior called “buzz pollination,” in which the bee grabs the pollen producing structure of the flower in her jaws and vibrates her wing muscles, dislodging pollen from the flower. In tomatoes, peppers, and cranberries, buzz pollination results in larger and more abundant fruit (Shaw *et al.* 1939, Banda and Paxton 1991, Kevan *et al.* 1983), and an industry of producing bumble bee colonies has grown out of the greenhouse tomato industry (Velthuis and van Doorn 2006). Losses of bumble bees can have far ranging ecological impacts due to their role as pollinators. In Britain and the Netherlands, where multiple bumble bee and other bee species have gone extinct, there is evidence of a decline in the abundance of insect pollinated plants (Biesmeijer *et al.* 2006).

In 2007, the National Research Council reported that long term population trends in several wild bee species (notably bumble bees) are demonstrably downward (National Research Council 2007). According to the National Research Council (2007), a major cause of decline in native bumble bees appears to be recently introduced nonnative fungal and protozoan parasites, including *Nosema bombi* and *Crithidia bombi*, probably introduced when colonies of North American bumble bees were reared in Europe then imported to the U.S. for commercial greenhouse pollination. Bees frequently harbor pathogens and their escape from greenhouses can lead to infections in native species (Colla *et al.* 2006, Otterstatter and Thomson 2008).

Bumble bee expert Dr. Robbin Thorp hypothesizes that wild populations of these three closely related North American bumble bees were infected with an introduced disease carried by commercially reared bumble bee colonies. In the early 1990's, common eastern (*B. impatiens*) and western (*B. occidentalis*) bumble bee queens were shipped to Europe. Colonies were raised from these queens in the same facilities as the European buff-tailed bumble bee (*B. terrestris*). These colonies were then returned to the U.S. for

use as commercial pollinators. Dr. Thorp suggests that, while in Europe, the common eastern and western bumble bees were exposed to a pathogen of the European buff-tailed bumble bee for which *B. occidentalis*, at least, had no prior resistance. Upon returning to the U.S., the common eastern and western bumble bees may have spread a highly virulent disease to wild populations of bumble bees belonging to the same group as the European buff-tailed bumble bee—the subgenus *Bombus*.

While a definitive link between pathogens and declines in these three species has not been made, the close relationship of the declining U.S. bee species to the European buff-tailed bumble bee, as well as the timing, speed, and severity of the population crashes, and the fact that other bumble bee species living in the same areas continue to thrive, suggest that an escaped exotic disease organism is the main cause of these widespread losses in members of the subgenus *Bombus*. However, there are a number of other threats that may be contributing to the losses of these bumble bees.

Habitat loss and fragmentation may be playing a role in the decline of these bumble bee species. Habitat alterations which destroy, fragment, degrade, or reduce their food supplies (flowers that produce the nectar and pollen they require), nest sites (e.g. abandoned rodent burrows or undisturbed grass), and hibernation sites for over-wintering queens all can harm these species. Threats that alter bumble bee habitat include agricultural intensification, livestock grazing, urban development, and fragmentation of landscapes. As bumble bee habitats become increasingly fragmented, the size of each population diminishes and inbreeding becomes more prevalent. Inbred populations of bumble bees show decreased genetic diversity and are at a greater risk of decline.

Insecticide applications may threaten populations of bumble bees of the subgenus *Bombus*. The National Academy of Science National Research Council's report on the Status of Pollinators in North America notes that bumble bees can be negatively affected by many pesticides. The report also points out that ground-nesting bumble bees are uniquely susceptible to pesticides that are used on lawns or turf (National Research Council 2007). Insecticide application on Forest Service managed public lands for spruce budworm has been shown to cause massive kills of bumble bees and reduce pollination of nearby commercial blueberries in New Brunswick (reviewed in Kevan and Plowright 1995). Broad-spectrum herbicides used to control weeds can indirectly harm bumble bees by removing the flowers that would otherwise provide the bees with pollen and nectar.

Other factors that may be threatening these bumble bee species include invasive plants and insects, air pollution, and climate change.

II. BIOLOGY, HABITAT REQUIREMENTS, POLLINATION ECOLOGY, AND TAXONOMY

A. Biology

Bombus affinis, *B. terricola*, and *B. occidentalis* all have similar natural histories. As with all other bumble bees, they live in colonies consisting of a queen and her offspring, the workers and males. There is a division of labor among these three types of bees. Queens are responsible for initiating colonies and laying eggs. Workers are responsible for most

food collection, colony defense, and feeding of the young. Males' sole function is to mate with queens. Bumble bee colonies depend on floral resources for their nutritional needs. Nectar provides them with carbohydrates and pollen provides them with protein.

Colonies are annual, starting from colony initiation by solitary queens in the spring, to production of workers, and finally to production of queens and males. Queens produced at the end of the colony cycle mate before entering diapause, a form of hibernation. *B. affinis*, *B. terricola*, and *B. occidentalis* queens emerge in spring and begin their search for appropriate nesting sites. The queen collects nectar and pollen from flowers to support the production of her eggs, which are fertilized by sperm she has stored since mating the previous fall. In the early stages of colony development, the queen is responsible for all food collection and care of the young. As the colony grows, workers take over the duties of food collection, colony defense, and care of the young. The queen then remains within the nest and spends most of her time laying eggs. Colonies typically consist of between 50 and 400 workers at their peak (Plath 1927; Thorp *et al.* 1983; Macfarlane *et al.* 1994) along with the queen. During later stages of colony development, new queens will be produced as well as males. Queen production is dependent on access to sufficient quantities of pollen. The amount of pollen available to bumble bee colonies directly affects the number of queens that can be produced (Burns 2004). Since queens are the only bumble bees capable of forming new colonies, pollen availability directly impacts future bumble bee population levels.

Bumble bees are generalist foragers, meaning that they gather pollen and nectar from a wide variety of flowering plants. Since bumble bee colonies obtain all their nutrition from pollen and nectar, they need a constant supply of flowers in bloom. Not all flowers are of equal value to bumble bees. Many varietal hybrids do not produce as much pollen and/or nectar as their wild counterparts (Frankie *et al.* 2005). Also, *B. affinis*, *B. terricola*, and *B. occidentalis* have short tongues. On average, worker's tongues in these species are around 5 to 7 mm in length, whereas some bumble bees have tongues as long as 10 mm (Medler 1962; Pyke 1982). Because of their short tongues, *B. affinis*, *B. terricola*, and *B. occidentalis* are not able to properly access the nectar in flowers with deep tubes. They will sometimes use their mandibles to chew holes in the bottom of these flowers to access the nectar from the outside of the flower, thus cheating the flower of pollination. The effect of this on plant fitness is variable, sometimes decreasing seed set, sometimes increasing it due to an increase in foraging activity (Irwin and Brody 1999; Maloof 2001). However, short-tongued bees are better suited for pollination of open flowers and those with short tubes, including cranberry (Patten *et al.* 1993). Longer tongue length increases flower handling time and reduces foraging efficiency when foraging on shorter tubed flowers (Inouye 1980; Plowright and Plowright 1997; Peat *et al.* 2005).

Bumble bees are more vulnerable to extinction than many other species due to their haplodiploid method of sex determination (Zayed and Packer 2005). As their populations become smaller, reduction in genetic diversity due to increased inbreeding results in an increase in production of non-viable diploid male bees.

B. Habitat requirements

B. affinis, *B. terricola*, and *B. occidentalis* require habitats with rich supplies of floral resources with continuous blooming from spring to autumn. Landscape level habitat quality has been shown to influence bumble bee species richness and abundance, indicating that isolated patches of habitat are not sufficient to fully support bumble bee populations (Hatfield and LeBuhn 2007; Öckinger and Smith 2007). *Bombus affinis*, *Bombus terricola*, and *Bombus occidentalis* primarily nest underground, typically in abandoned rodent nests located from six to eighteen inches below the surface (Plath 1927; Thorp *et al.* 1983; Lavery and Harder 1988). Occasionally nests will be constructed on the surface in areas such as clumps of grass on the ground (Hobbs 1968; Macfarlane *et al.* 1994). Thus, nesting sites may be limited by the abundance of rodents and the presence of undisturbed grassland.

C. Pollination Ecology

During collection of pollen and nectar from flowers, bumble bees also transport pollen between flowers, enabling seed and fruit production. Bumble bees are an excellent alternative or supplement to honey bees for pollination of many crops. There are several attributes shared by all bumble bees that promote their use as pollinators of commercial crops. Bumble bees have been shown to fly in cooler temperatures and lower light levels than many other bees, which extends their work day and improves the pollination of crops during inclement weather (Corbet *et al.* 1993). Bumble bees perform a behavior called “buzz pollination.” In buzz pollination, the bee grabs the pollen producing structure of the flower in her jaws and vibrates her wing musculature causing vibrations that dislodge pollen that would have otherwise remained trapped in the flower’s anthers (Buchmann 1983). Some plants, including tomatoes, peppers, and cranberries, require this vibration for pollination. These factors contribute to the effectiveness of bumble bees as commercial pollinators. *Bombus affinis*, *B. terricola*, and *B. occidentalis* all have great potential as pollinators of commercial crops due to their early emergence in spring, their ability to be reared in captivity, and their large colony sizes (Macfarlane *et al.* 1994). Bumble bees also adapt very well to the greenhouse environment, making them the primary pollinating force for the greenhouse industry.

In addition to commercially important crops, bumble bees also play a vital role as pollinators of native flowering plants. Bumble bees are generalist foragers, meaning that they do not depend on any one flower type. However, some plants do rely on bumble bees to achieve pollination. The loss of bumble bees has far ranging ecological impacts due to their role as pollinators. An examination of the theoretical effect of removal of specialist and generalist pollinators on the extinction of plant species concluded that the loss of generalist pollinators poses the greatest threat to pollinator networks (Memmott *et al.* 2004). In Britain and the Netherlands, where multiple bumble bee species, as well as other bees, have gone extinct, there is evidence of decline in the abundance of insect pollinated plants (Biesmeijer *et al.* 2006).

D. Taxonomy

All bumble bees belong to the genus *Bombus* within the family Apidae. There are approximately 250 described species of bumble bees in the world, and over 50 species in

North America (Williams 1998). The family Apidae includes the well-known and economically important honey bees and bumble bees, as well as carpenter bees, cuckoo bees, digger bees, stingless bees, and orchid bees. The three species of concern for this review, *Bombus affinis*, *Bombus terricola*, and *Bombus occidentalis*, all belong to the same subgenus of *Bombus*, *Bombus sensu stricto*. *Bombus sensu stricto* is well supported as a distinct subgenus (Williams *et. al* 2008).

Bombus affinis Cresson was first described by Cresson (1863). Its status as a unique species was recently upheld by Williams (1998) and Cameron *et al.* (2007).

Bombus terricola Kirby was first described by Kirby (1837). Its status as a unique species was recently upheld by Williams (1998) and Cameron *et al.* (2007).

Bombus occidentalis was first described by Greene (1858). *B. occidentalis* has been regarded both as a subspecies of *B. terricola* (Milliron 1971; Poole 1996; Williams 1998) and as a unique species (Franklin 1913; Stephen 1957; Hobbs 1968; Thorp *et al.* 1983; Scholl *et al.* 1990, 1992). Many people currently treat *B. terricola* and *B. occidentalis* as separate species. However, the existent of apparent intergradations in broad parts of their ranges indicates that they may be conspecific (P. Williams, personal communication, July 2008). In this status review, we treat *B. occidentalis* as a unique species. However, even if it were determined to belong to the same species as *B. terricola*, *B. occidentalis* would be considered a subspecies of *B. terricola* (*B. terricola occidentalis*).

Other North American species in the subgenus *Bombus sensu stricto* not treated here are: *B. franklini* (Frison) and *B. moderatus* Cresson (= *B. lucorum* (L.) in the broad sense according to Milliron 1971; = *B. cryptarum* (F.) [of the *lucorum*-complex] according to P. Williams, personal communication, July 2008). Both of these bees were not formerly wide ranging, as were *B. occidentalis*, *B. terricola*, and *B. affinis*. *B. franklini* has the most restricted range of any bumble bee species (Williams 1998). *B. franklini* numbers have dropped dramatically since 1998, possibly due to the same causes as other members of *Bombus sensu stricto* (Thorp 2005) and may be extinct (Note: The authors are preparing a sparate status review for *B. franklini*). *B. moderatus* populations are limited to northwestern Canada and Alaska (Milliron 1971).

III. THE RUSTY-PATCHED BUMBLE BEE, *BOMBUS AFFINIS* CRESSON

A. Species Description

Queens and Workers:

Bombus affinis queens and workers differ slightly in coloration (an uncommon feature in bumble bees), the primary difference being size and a medial rusty patch present on the second abdominal segment on the worker. Queens are 21 to 22 mm in length, 9.5 to 11 mm in breadth (Mitchell 1962). Workers are 11 to 16 mm in length, 5 to 9 mm in breadth (Mitchell 1962). Their hair is entirely black on the head, the bottom of the thorax, and in large part on the legs. The rest of the thorax has mostly yellow hair, with a black area in the middle of the thorax. Their hair is entirely yellow on the first two abdominal segments and black on the rest of the abdomen. On workers, there is more black intermixed with yellow near the base of the wings forming somewhat of an interalar band

and with black hairs extending rearward in a narrow V that partially bisects the yellow on the scutellum. The second abdominal segment has a rusty reddish patch centrally, with yellow hairs around the edges of the segment. See figure 1 for illustrations of *B. affinis* queen, worker and male.



Figure 1. Illustrations of *Bombus affinis* queen (left), worker (center), and male (right) by Elaine Evans.

Males:

Bombus affinis males are 13 to 17.5 mm in length with a breadth of 5 to 7 mm (Mitchell 1962). Their hair is largely black on the head, but with a few pale hairs intermixed near the top of the head. Black hairs sometimes form an obscure band across the middle of the thorax, otherwise the hair on the thorax is largely pale yellowish. The first two abdominal segments have pale yellow hair. The hair on the rest of the abdominal segments is black.

B. Pollination Ecology

Bombus affinis has been shown to be an excellent pollinator of cranberry (Cane and Schiffauer 2003). They have also been shown to pollinate other important crops such as plum and apple (Medler and Carney 1963; Mitchell 1962), alfalfa (Holm 1966), and onion for seed production (Caron *et al.* 1975).

Bombus affinis visits a wide variety of wild plants including *Abelia grandiflora* (Speight 1967), *Aesculus* spp. (Dieringer 1982; Macfarlane 1974), *Agastache foeniculum* (C. Reed, personal communication, July 2008), *Amorpha canadense* (C. Reed, personal communication, July 2008), *Asclepias syriaca*, *A. incarnata*, *A. verticillata* (Frost 1965; Macior 1965), *Aralia* spp. (Mitchell 1962), *Aster* spp. (Costelloe 1988), *Aquilegia canadensis* (Macior 1978a), *Aureolaria pedicularia* (Stiles 1977), *Berberis* spp. (Macior 1965), *Camassia scilloides* (Macior 1978b), *Carduus* sp. (Macior 1965), *Ceanothus americanus* (Bequaert 1920), *Cercis canadensis* (Fye and Medler 1954), *Chamaedaphne calyculata* (Judd 1966), *Coreopsis major* (Speight 1967), *Crataegus* spp. (Macior 1968a), *Dalea purpurea* (C. Reed, personal communication, July 2008), *Delphinium tricornis* (Macior 1975), *Dicentra canadensis*, *D. cucullaria* (Macior 1978b), *Echium vulgare* (Macfarlane 1974), *Helianthus* spp. (Fye and Medler 1954; Colla and Packer 2008), *Hydrangea* spp. (Mitchell 1962), *Hydrophyllum* spp. (Macior 1978b, Macfarlane 1974), *Impatiens capensis* (R. Gegear, personal communication, May 2008), *Lamium*

purpureum (Macior 1978a), *Laportea* spp. (Speight 1967), *Leonurus* sp. (Macior 1965), *Linaria* sp. (Macior 1965), *Lonicera* spp. (Macior 1968a), *Lotus corniculatus* (Fye and Medler 1954), *Medicago sativa* (Fye and Medler 1954), *Mertensia virginica* (Macior 1978b), *Monarda* sp. (Macior 1965), *Nepeta* spp. (Macior 1965), *Pedicularis canadensis* (Macior 1978b; Dieringer 1982), *Pedicularis lanceolata* (Costelloe 1988; Macior 1969), *Penstemon grandiflorus* (C. Reed, personal communication, July 2008), *Philadelphus* spp. (Speight 1967), *Polymnia* spp. (Speight 1967), *Prunella vulgaris* (Speight 1967), *Prunus* spp. (Fye and Medler 1954), *Pyrus ioensis* (Macior 1968a), *Pyrus malus* (Macior 1968a), *Ratibida pinnata* (C. Reed, personal communication, July 2008), *Rhododendron* spp. (Macfarlane 1974), *Rhus* spp. (Speight 1967), *Ribes* spp. (Macfarlane 1974) *Robinia* spp. (Mitchell 1962), *Rosa* spp. (Macior 1965), *Rubus* spp. (Macfarlane 1974), *Salix* spp. (Medler and Carney 1963), *Sarracenia purpurea* (Ne'eman *et al.* 2006), *Solanum* sp. (Macior 1965), *Solidago* spp. (Mitchell 1962), *Symphytum officinale* (Macfarlane 1974), *Syringia* spp. (Macior 1968a), *Syringia vulgaris* (Fye and Medler 1954), *Taraxacum* spp. (Macior 1968a), *Trifolium* spp. (Fye and Medler 1954; Macfarlane 1974), *Vaccinium* spp. (Mitchell 1962), *Verbascum* spp. (Macior 1965), *Verbesina occidentalis* (Speight 1967), *Vicia* spp. (Fye and Medler 1954; Macfarlane 1974).

C. Population Distribution and Status

Historically, *Bombus affinis* was widely distributed in southeastern Ontario and southern Quebec and along the east coast of the United States from southern Maine south through Georgia with an extension west along the northern states through Minnesota (see Figure 2; Mitchell 1962; Milliron 1971), with a few specimens found as far west as North Dakota (Stevens 1948). In the U.S., states in *B. affinis*' historic range included Minnesota, Wisconsin, Indiana, Ohio, Pennsylvania, New York, New Jersey, Delaware, Vermont, New Hampshire, Maine, Maryland, Massachusetts, Connecticut, West Virginia, Virginia, North Carolina, South Carolina, Georgia, and portions of Michigan, North Dakota, South Dakota, Iowa, Illinois, Kentucky, and Tennessee. Canadian provinces included in its historic range are Ontario and Quebec. See Appendix IA for a list of some of the *B. affinis* museum records from major collections.

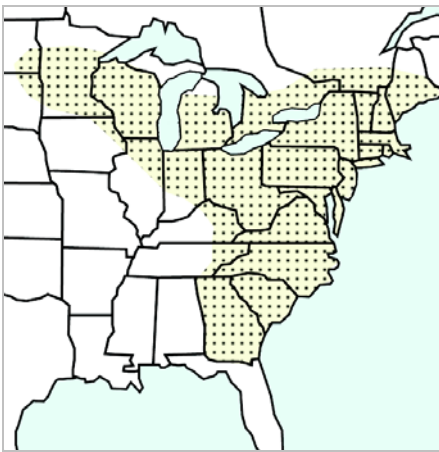


Figure 2. Historic distribution of *Bombus affinis*. Map is based on *A monograph of the western hemisphere bumblebees* by Milliron (1971).

Although this species was formerly commonly found throughout most of its range, surveys between 2003 and present have found very few *B. affinis*. Below are findings from some recent studies; tables 1 and 2 contain summaries of many of the recent and historical surveys for *B. affinis* and the abundance of this species relative to other bumble bees in the survey.

Northeastern United States and Eastern Canada:

In a study from 1971 to 1973 of bumble bees in southern Ontario, approximately 14% of 3,632 bumble bees collected were *B. affinis* (Macfarlane 1974). A study sampling 1,195 bumble bees from the same sites in Ontario from 2004 to 2006 found no *B. affinis* individuals (Colla and Packer 2008, see Figure 3). Additionally, in the same study, of approximately 9,000 bumble bees collected from 43 sites in the historic range of *B. affinis* in Canada and the eastern U.S., only a single *B. affinis* individual was found. This single *B. affinis* was collected in Ontario, Canada; no *B. affinis* were found at sites in the United States. *B. affinis* was formerly abundant in Toronto, Ontario in 1983 but has not been seen during regular surveys in the Toronto area from 2003 to 2008 (P. Williams, personal communication, July 2008). A 2003 survey including over 1,261 bumble bees in New York, where *B. affinis* was considered historically to be “moderately abundant in the eastern to southern parts of the [New York] state...” (Leonard 1928), failed to find any *B. affinis* (Giles and Ascher 2006). In the same research paper, the authors noted that *B. affinis* is well represented in historical collections from the northeastern U.S. (Giles and Ascher 2006). In a sample of nearly 1,000 bumble bees on the Patuxent National Wildlife Refuge in Maryland from 2002 to 2007, a single *B. affinis* specimen was collected in 2002 and none have been collected since (S. Droege, personal communication, February 2008). The same researcher reports that *B. affinis* were numerous in collections in the 1980s in areas near Patuxent National Wildlife Refuge north of Baltimore, Maryland and in northern Delaware (S. Droege, personal communication, February 2008).

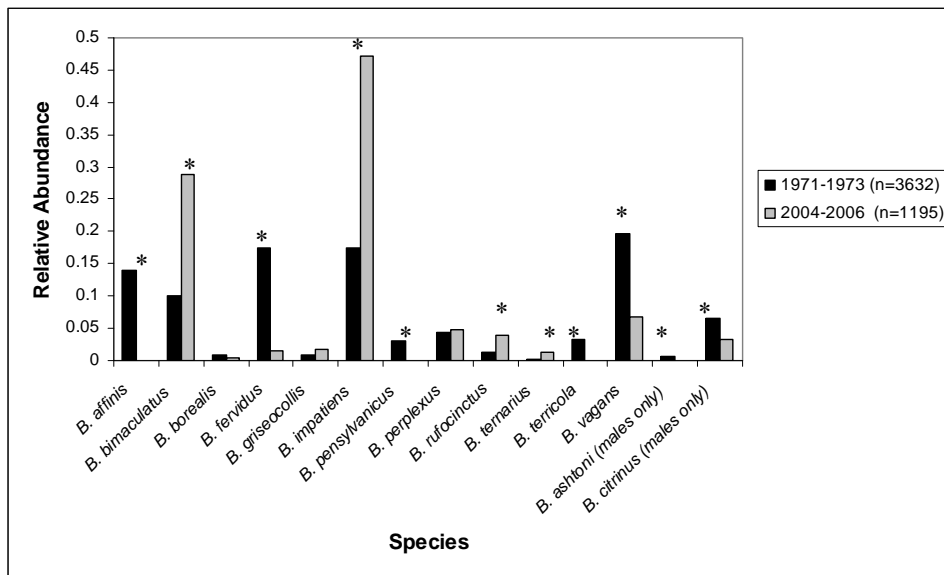


Figure 3. Comparison of the relative abundance of each bumble bee species collected in southern Ontario from 1971-1973 (black) (Macfarlane 1974) and 2004-2006 (gray) (*indicates that there is a significant difference between the relative abundance of a

bumble bee species in the 2004-2006 study and the 1971-1973 study; $P < 0.001$). Figure courtesy of Sheila Colla (Colla and Packer 2008).

Midwestern United States:

A multi-year survey of bee species in northern Indiana including over 880 bumble bees found 25 *B. affinis* specimens out of 217 (12%) in 2001, two out of 451 (0.004%) in 2002, and none out of 553 in 2003 (R. Jean and P. E. Scott personal communication, September 2007). A similar pattern was seen in surveys in Iowa with five *B. affinis* found in 2000, five in 2001, and none in 2002 (S. Hendrix and C. Gienapp, personal communication, September 2007). In 1993, a survey of a prairie near the Fermi National Accelerator Laboratory in Illinois found that 112 of the total 1,113 bumble bees collected, or approximately 10%, were *B. affinis* (Franzen 1993; S. Sheehan, personal communication, March 2008). In a more recent study of pollinators in 2003 and 2004 in the same area, only one out of 84 bumble bees collected was *B. affinis* (~ 1%) (S. Sheehan, personal communication, March 2008). Although this sample is too small to make definitive conclusions, it does suggest that *B. affinis* may be less common. Surveys at 20 different sites across in Illinois in 2006 found one *B. affinis* out of 583 bumble bees collected (C. North, personal communication, October 2007). In 2007, approximately 40 *B. affinis* were found at one site out of 230 bumble bees collected in McHenry County, Illinois (Grixti and Favret, personal communication, November 2007). In the same study, single *B. affinis* specimens were found at three other sites: in Champaign County one out of 70 (0.1%), in Peoria County one out of 25 (0.04%), and Dewitt County one out of 40 (0.025%) bumble bees were collected. Grixti *et al.* (in press) examined historical records for *B. affinis* and found that the distribution of *B. affinis* has declined by nearly one-third since 2000, with only 67% of its pre-2000 distribution remaining. Grixti *et al.* (in press) did find a small increase in the relative abundance of *B. affinis* between 2000 and 2007 compared to the relative abundance from 1900 to 1999 (1.4% in 2000 to 2007 compared to 0.6% for 1900 to 1949 and 0.3% for 1950 to 1999). However, Grixti *et al.* state that this finding is misleading because 90% of the 50 *B. affinis* workers that were sampled during the entire study were collected from a single site. In August of 2008, another *B. affinis* specimen was observed near Peoria, Illinois (J. James-Heinz, personal communication September 2008). A 1994 to 1995 survey including 464 bumble bees at Long Lake Regional Park in New Brighton, Minnesota found 98 (21%) *B. affinis* individuals (Reed 1995; C. Reed, personal communication, June 2007). A 2007 to 2008 survey at the same park including 593 bumble bees found no *B. affinis* (E. Evans, personal observation, July 2008). One specimen was seen and photographed in Wisconsin in 2006 (<http://bugguide.net/node/view/80952#93112>).

Southeastern United States:

B. affinis has not been seen in the Great Smoky Mountains National Park in North Carolina and Tennessee, where it was once abundant, since 2000 (A. J. Mayor, personal communication, September 2007). Surveys of spring queens in North Carolina consistently found *B. affinis* from 1995 to 2001, yet between 2002 and 2007, no *B. affinis* queens were found while other bumble bee species were present (R. Jacobson, personal communication, September 2007). A survey in Virginia between 2002 and 2005 including 283 bumble bees found no *B. affinis* (T. Roulston, personal communication,

September 2007).

Surveys prior to 2002					Surveys from 2002-2008				
Region	Researcher/ Publication	Survey year(s)	Total # of bumble bees collected	Relative abundance of <i>B. affinis</i> in collection	Region	Researcher/ Publication	Survey year(s)	Total # of bumble bees collected	Relative abundance of <i>B. affinis</i> in collection
Southern Ontario (26 sites)	MacFarlane (1974)	1971-1973	3,632	14%	Southern Ontario (26 sites)	Colla & Packer (2008)	2004-2006	1,195	0%
Fermi National Accelerator Laboratory, Batavia, Illinois	Franzen (1993)	1993	1,113	10%	Fermi National Accelerator Laboratory, Batavia, Illinois	S. Sheehan (pers. comm. March 2008)	2003-2004	84	1%
Long Lake Regional Park, New Brighton, Minnesota	Reed (1995, pers. comm. June 2007)	1995	464	21%	Long Lake Regional Park, New Brighton, Minnesota	E. Evans (pers. obs.)	2007-2008	593	0%
Northern Indiana	R. Jean & P. E. Scott (pers. comm. Sept. 2007)	2001	217	12%	Northern Indiana	R. Jean & P. E. Scott (pers. comm. Sept. 2007)	2002	451	0.004%
Northern Indiana	R. Jean & P. E. Scott (pers. comm. Sept 2007)	2001	217	12%	Northern Indiana	R. Jean & P. E. Scott (pers. comm. Sept. 2007)	2003	553	0%

Table 1. Comparison of *B. affinis* relative abundance prior to 2001 and since 2001.

Historic status of <i>B. affinis</i>	Region	Researcher/ Publication	Survey year(s)	Total # of bumble bees collected	Relative abundance of <i>B. affinis</i>
<i>B. affinis</i> was considered “moderately abundant in the eastern and southern parts of the [New York] state” (Leonard 1928: 1031; cited in Giles & Ascher 2006)	New York state	Giles & Ascher (2006)	2003	1,261	0%
<i>B. affinis</i> were numerous in collections in the 1980s in areas near Patuxent NWR north of Baltimore, Maryland and in northern Delaware (S. Droege, pers. comm. Feb. 2008)	Patuxent NWR, Maryland	S. Droege (pers. comm. Feb. 2008)	2002-2007	nearly 1,000	~0.1%
<i>B. affinis</i> was regularly collected in Illinois between 1900 and 2000 but was not abundant (Grixti <i>et al.</i> in press)	Illinois (20 sites)	C. North (pers. comm. Oct. 2007)	2006	583	0.17%
<i>B. affinis</i> was regularly collected in Illinois between 1900 and 2000 but was not abundant (Grixti <i>et al.</i> in press)	Illinois (1 site)	J. Grixti & C. Favret (pers. comm. Nov. 2007)	2007	230	17%
<i>B. affinis</i> was regularly collected in Illinois between 1900 and 2000 but was not abundant (Grixti <i>et al.</i> in press)	Champaign County, Illinois	J. Grixti & C. Favret (pers. comm. Nov. 2007)	2007	70	0.1%
<i>B. affinis</i> was regularly collected in Illinois between 1900 and 2000 but was not abundant (Grixti <i>et al.</i> in press)	Peoria County, Illinois	J. Grixti & C. Favret (pers. comm. Nov. 2007)	2007	25	0.04%
<i>B. affinis</i> was regularly collected in Illinois between 1900 and 2000 but was not abundant (Grixti <i>et al.</i> in press)	Dewitt County, Illinois	J. Grixti & C. Favret (pers. comm. Nov. 2007)	2007	40	0.025%
information on historic status not readily available	Virginia	T. Roulston (pers. comm. Sept. 2007)	2002-2005	283	0%

Table 2. Relative abundance of *B. affinis* in recent surveys.

Parallel decline of a cuckoo bee:

B. affinis, as well as *B. terricola*, declines have likely caused a severe reduction in *Bombus ashtoni* populations. *Bombus ashtoni* is a bumble bee species that parasitizes other bumble bees by entering nests and using the worker force of the host colony to raise their young instead of the queen’s progeny. *B. ashtoni* exclusively parasitizes *B. terricola* and *B. affinis* (Plath 1934; Fisher 1984; Laverty and Harder 1988). *B. ashtoni* has not

been found in any parts of its former range since 2000 (J. Ascher, personal communication, August 2008). Since parasitic bumble bees are dependent on their hosts for reproduction, declines in host numbers can have severe effects on parasitic bumble bee's populations. Decline of *B. affinis* and *B. terricola* populations is the most likely cause of the possible extinction of *B. ashtoni*. The absence of *B. ashtoni* since 2000 provides indirect evidence of a decline of their hosts, *B. affinis* and *B. terricola*.

Summary:

B. affinis was once widespread and relatively common across 26 states and two Canadian provinces. The data and observations detailed above indicate that this species has undergone a dramatic decline in nearly all areas that scientists and collectors have revisited.

IV. The Yellowbanded Bumble Bee, *Bombus terricola* Kirby

A. Species description

Queens and Workers:

Bombus terricola queens and workers are similar in coloration. The queen is 17 to 19 mm in length, 9 to 10 mm in breadth. The worker is 8 to 15 mm in length, 5 to 8 mm in breadth. Their hair is nearly entirely black on the head. Their hair is yellow on the front part of the thorax and the second and third abdominal segments. There is a fringe of brownish yellow hairs on the fifth abdominal segment. Otherwise, the hair is primarily black including that on the legs and the base of the abdomen, with some variation in coloration of hairs on the rear section of the thorax as well as abdomen.

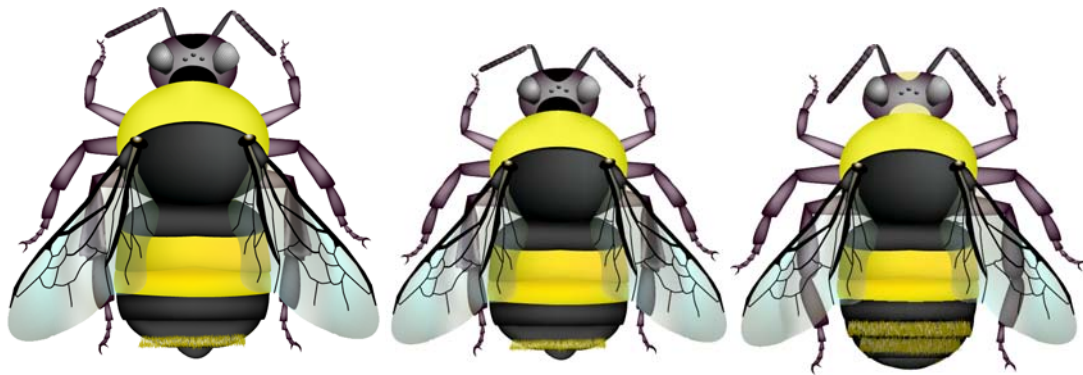


Figure 4. Illustrations of *Bombus terricola* queen, worker, and male by Elaine Evans.

Males:

Bombus terricola males are 13 to 17 mm in length, 6 to 8 mm in breadth. Their hair is pale and yellowish on the front of the face, with intermixed black hairs on the sides, and mostly black hairs around the antennae. The top of the head has pale yellowish hairs intermixed with black, especially laterally. Their hair is pale yellowish on the front of the thorax and black over the posterior two-thirds of the thorax. The second and third abdominal segments have bright yellow hair. Abdominal segments one and five to six have hair that is largely black.

B. Pollination Ecology

Bombus terricola has been shown to be an important pollinator of male-fertile potato flowers for production of seed (Batra 1993). *Bombus terricola* also pollinates alfalfa (Stephen 1955; Holm 1966), *Rubus* spp. (Mitchell 1962), lowbush blueberry (Javorek *et al.* 2002), and cranberry (MacKenzie and Averill 1995).

Bombus terricola visits a wide variety of wildflowers including *Agastache foeniculum* (C. Reed, personal communication, July 2008), *Ajuga* spp. (Macfarlane 1974), *Anaphalis margaritacea* (Fye and Medler 1954), *Apocynum androsaemifolium* (Plowright and Plowright 1998), *Asclepias syriaca* (Jennersten *et al.* 1991; Plowright and Plowright 1998), *Aster azureus*, *Berberis thunbergii* (Macfarlane 1974), *Brassica nigra*, *Carduus nutans* (Macfarlane 1974), *Cirsium arvense*, *C. vulgare* (Fye and Medler 1954), *Cotoneaster adpressa* (Macfarlane 1974), *Dalea purpurea* (C. Reed, personal communication, July 2008), *Echium vulgare* (Macfarlane 1974), *Epilobium angustifolium* (Macior 1978c; Galen and Plowright 1985), *Hieracium aurantiacum* (Plowright and Galen 1985), *Hydrophyllum virginianum* (Macfarlane 1974), *Hypericum perforatum*, *Liatris aspera*, *Linaria vulgaris*, *Linus* spp., *Lonicera* spp., *Lotus corniculatus*, *Lychnis alba*, *Medicago sativa*, *Melilotus alba*, *M. indica* (Fye and Medler 1954), *Minuartia groenlandica* (Levesque and Burger 1982), *Pedicularis furbishiae* (Macior 1978c), *Potentilla tridentata* (Levesque and Burger 1982), *Prunus* spp., *Pyrus malus* (Fye and Medler 1954), *Rhododendron* spp., *Ribes* spp. (Macfarlane 1974), *Robinia* spp. (Mitchell 1962), *Rosa acicularis*, *Rosa carolina*, *Rubus* spp., *Salix* spp. (Fye and Medler 1954), *Solanum dulcamara* (Macfarlane 1974), *Solidago* spp., *Symphytum officinale* (Macfarlane 1974), *Syringia vulgaris*, *Taraxacum* spp., *Tilia platyphyllos* (Macfarlane 1974), *Trifolium repens*, (Fye and Medler 1954), *Silene cucubalus*, *Spiraea latifolia*, *Thalictrum dasycarpum*, *Trifolium hybridum*, *T. pratense*, *Vicia cracca* (Macior 1978c), *Viburnum lentago* (Fye and Medler 1954), and *Weigelia florida* (Macfarlane 1974).

C. Population Distribution and Status

Until recently, *Bombus terricola* was commonly found east of the Rockies in the northern United States and into southern Canada, from eastern Montana and Alberta, across the northern states and southern portion of the Canadian provinces through to the east coast, with a southern extension along the Appalachian Mountains in the eastern U.S. (Mitchell 1962; Milliron 1971). In the southeastern U.S., *B. terricola* seems to be restricted to higher elevations (Speight 1967). In Canada, the historic range of *B. terricola* extended northwest into central British Columbia (Stephen 1957). U.S. states included in *B. terricola*'s historic range are Montana, South Dakota, North Dakota, Minnesota, Wisconsin, Michigan, Pennsylvania, New York, Vermont, New Hampshire, Maine, West Virginia, and portions of Illinois, Ohio, Massachusetts, Maryland, Rhode Island, Connecticut, Virginia, Tennessee, Kentucky, and North Carolina. Canadian provinces included in its historic range are Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Foundland, and Nova Scotia. See Appendix IB for a list of some of the *B. terricola* records from major museum collections.

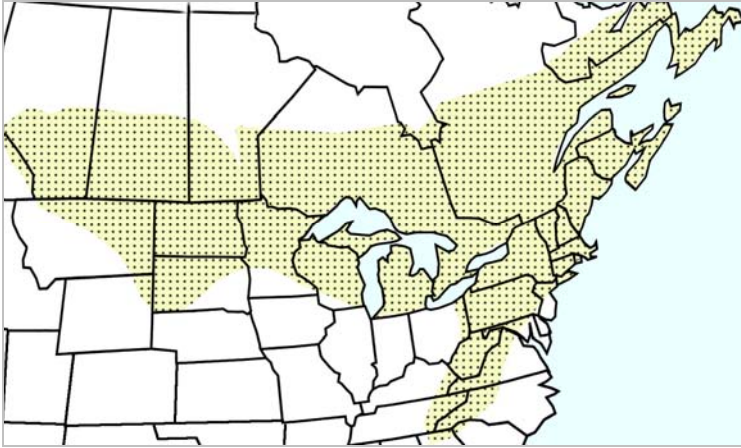


Figure 5. Historic distribution of *Bombus terricola*. Map is based on *A monograph of the western hemisphere bumblebees* by Milliron, 1971.

Bombus terricola was considered to be very common in North Dakota (Stevens 1948). Medler and Carney (1963) predicted that urbanization and intensification of land use would lead to a decline in *B. terricola* in the southern part of its range in Wisconsin. However, *B. terricola* remained fairly common in the 1990s. *B. terricola* accounted for 22% of central Wisconsin bumble bees and 93% of northern Wisconsin bees in a 1995 survey (Macfarlane 1998). In the late 1960s, Hobbs (1968) described the abundance of *B. terricola* in Alberta as “probably the most common bumble bee in the Peace River region” (west northern Alberta). Below are findings from recent studies and tables 3 and 4 summarize recent and historic surveys for *B. terricola* and the abundance of this species relative to other species of bumble bees.

Northeastern United States and Eastern Canada:

A study from 1971 to 1973 in southern Ontario including 3,632 bumble bees found 119 (3%) *B. terricola* (Macfarlane 1974). In a study from 2004 to 2006 at the same sites in southern Ontario, Sheila Colla collected 1,195 bumble bees, and found only a single (0.001%) *B. terricola* (Colla and Packer 2008). A comparison of the abundance of *B. terricola* relative to other bumble bee species over the two collection periods revealed that *B. terricola* has significantly declined since the early 1970s (Colla and Packer 2008, Figure 3). *B. terricola* was found to be abundant in Toronto, Ontario in 1983 but has not been seen during regular large scale surveys in the Toronto area in 2003 to 2008 except for one male in 2005 and one worker in 2006 (P. Williams, personal communication, July 2008). Formerly, *B. terricola* was commonly found in Maine and Vermont (B. Heinrich, personal communication, September 2007). Heinrich (2004) in the new preface to the re-release of his classic book, Bumblebee Economics, failed to find any *B. terricola* for several years at sites in these two states where it formerly had been abundant. In 2007, he observed 679 bumble bees in Maine and Vermont and found a total of three *B. terricola* (B. Heinrich, personal communication, September 2007). A 2003 survey in New York including over 1,261 bumble bees failed to find any *B. terricola* (Giles and Ascher 2006).

Although absent from most its range since 2000, recently *B. terricola* has been found in isolated parts of its range in 2005 to 2008. *B. terricola* was collected in New Hampshire

as recently as 2007, Massachusetts as recently as 2002 (M. Veit, personal communication, June 2008). Several *B. terricola* workers were found in Sprout State Forest in Pennsylvania in 2006, although no *B. terricola* were found at the same location in 2007 (R. Jacobson, personal communication, September 2007). In 2008, several *B. terricola* were seen at each of three sites in Maine (B. Heinrich, personal communication, August, 2008). *Bombus terricola* were seen by another observer at four different sites in Vermont in 2008 (L. Richardson, personal communication, August 2008). Two *B. terricola* workers were observed in Nova Scotia in 2008 (K. MacKenzie, personal communication, July 2008).

Midwestern United States:

In a 1995 survey, *B. terricola* accounted for 93% of northern Wisconsin bees (Macfarlane 1998). Bumble bee collector Dale Reimer had been searching regularly, but had not seen any *B. terricola* at a site where they were formerly common around Mountain, Wisconsin (Oconto County) since 2003. In 2007 and 2008, Reimer observed several dozen specimens within a 15 mile radius around the town of Mountain (D. Reimer, personal communication, March 2008). One *B. terricola* was collected in 2001 at Manitowish Waters, Wisconsin and in 2008 a nest was sited in Two Rivers, Wisconsin for the first time since 2001 (D. Reimer, personal communication, July 2008). A specimen was photographed in Nova Scotia in 2007 (J. DeLong, personal communication, January 2008). In April, 2008, a queen *B. terricola* was seen near Manitowoc, east-central Wisconsin, where *B. terricola* has been absent or nearly so for several years (Liz Day, Bombus List-serv, April, 2008). An examination of historical records revealed that *B. terricola* was present in parts of Illinois in 1900 to 1949, but has been absent since that time (Grixti *et al.* in press).

Southeastern United States:

B. terricola has been observed in Tennessee in 2006 although it was absent from collections between 1999 and 2006 (A.J. Mayor personal communication September, 2007). *B. terricola* was also observed at another location in Tennessee in 2008 (R. Bettge, personal communication, August, 2008).

Historical survey					Recent survey				
Region	Researcher / Publication date	Year(s)	Total # of bumble bees collected	Relative abundance of <i>B. terricola</i> in collection	Region	Researcher / Publication date	Year(s)	Total # of bumble bees collected	Relative abundance of <i>B. terricola</i> in collection
Southern Ontario (26 sites)	Macfarlane	1971-1973	3,632	3%	Southern Ontario (26 sites)	Colla & Packer (2008)	2004-2006	1,195	0.001%

Table 3. Comparison of survey before 1999 and a more recent survey of *B. terricola*.

Historic abundance	Region	Researcher / Publication date	Year(s)	Total # of bumble bees collected	Relative abundance of <i>B. terricola</i> in collection
<i>B. terricola</i> was formerly common in Maine and Vermont (B. Heinrich pers. comm. Sept. 2007)	Maine and Vermont	Heinrich	2007	679	0.4%
information on historic status not available	New York	Giles & Ascher (2006)	2003	1,260	0%

Table 4. Relative abundance of *B. terricola* in recent surveys.

Parallel decline of a cuckoo bee:

B. terricola, as well as *B. affinis*, declines have likely caused a severe reduction in *Bombus ashtoni* populations. *Bombus ashtoni* is bumble bee species that parasitizes other bumble bees by entering nests and using the worker force of the host colony to raise their young instead of the queen's progeny. *B. ashtoni* exclusively parasitizes *B. terricola* and *B. affinis* (Plath 1934; Fisher 1984; Lavery and Harder 1988). *B. ashtoni* has not been found in any parts of its former range since 2000 (J. Ascher, personal communication, August 2008). Since parasitic bumble bees are dependent on their hosts for reproduction, declines in host numbers can have severe effects on parasitic bumble bee's populations. Decline of *B. affinis* and *B. terricola* populations is the most likely cause of the possible extinction of *B. ashtoni*. The absence of *B. ashtoni* since 2000 provides indirect evidence of a decline of their hosts, *B. affinis* and *B. terricola*.

Summary

Bombus terricola was once common and widespread across 21 U.S. states and seven Canadian provinces. Although some individuals were recently found in isolated parts of its range between 2005 and 2008, the observations and data presented above suggest that this bumble bee has drastically declined in large parts of its range.

V. THE WESTERN BUMBLE BEE, BOMBUS OCCIDENTALIS GREENE

A. Species Description (n nominate form)

Queens and Workers:

Bombus occidentalis queens and workers are similar in coloration. The queen is 17 to 19 mm in length, 9 to 10 mm in breadth. The worker is 9 to 14 mm in length, 5 to 7 mm in breadth. Their hair is entirely black on the head. Their hair is yellow on the front part of the thorax. The first through the basal section of the fourth abdominal segments have black hair. The apex of the fourth abdominal segment as well as segments five and six are whitish. The hair on their legs is black.

Males:

The male is 13 to 17 mm in length, 6 to 8 mm in breadth. The hair on the head is pale yellowish on the front of the face. The top of the head has pale yellowish hairs medially, with some black hairs, especially laterally. The hair on the front of the thorax is pale yellowish. The hair on the first to third abdominal segments is black. The basal part of the fourth abdominal segment is black, with the remainder, as well as segments five to seven, whitish.

While *B. affinis* and *B. terricola* exhibit some color variation throughout their ranges, *B. occidentalis* is the most chromatically variable North American species in the subgenus *Bombus*. Franklin (1913) describes twelve female and twelve male variants of this species in his revision of New World bumble bees. As a result, many variety names have been applied to this species. Major color variants of *B. occidentalis* females, pictured in Figure 6, include:

Variety 1: As nominate form above, but with apical and lateral margins of the second abdominal segment and all of the third with yellow hair. Hair of segment five is reddish brown [= *B. occidentalis nigroscutatus* Franklin, CA Coast Ranges].

Variety 2: As nominate form above, but with scutellum (posterior thorax behind wings) with yellow, apex of second abdominal segment and all of third with yellow. [= *B. proximus* Cresson, AK, BC, UT, CO, NM].

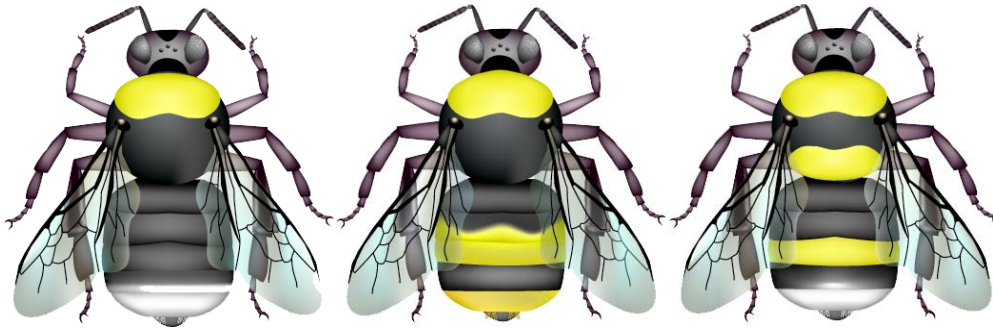


Figure 6. Pictured on the left is the nominate form of a *Bombus occidentalis* worker; pictured in the center is Variety 1 of a *Bombus occidentalis* worker; pictured on the right is Variety 2 of a *Bombus occidentalis* worker. Illustrations by Elaine Evans.

B. Pollination Ecology

Commercially reared colonies of *Bombus occidentalis* have been used extensively for pollination of greenhouse tomatoes and field berry crops in the western U.S. Wild colonies of *B. occidentalis* also have been significant pollinators of cranberry (Patten *et al.* 1993). *B. occidentalis* has been used for field pollination of alfalfa (Stephen 1955; Hobbs *et al.* 1961) and avocado (Pidduck and McNeil 2001). *B. occidentalis* also pollinates commercially important crops such as apples, cherries, blackberries, and blueberry (Macfarlane and Patten 1997). Additionally, *B. occidentalis* was tested for use in almond pollination in Dixon and Ripon, California in 1993, 1995, and 1996 (Thorp unpublished); and on caged almond trees in Chico, California in 1994 (Davies 1995).

Bombus occidentalis visits a wide variety of wildflowers including *Aster* spp. (Thorp *et al.* 1983), *Brassica* spp. (Thorp *et al.* 1983), *Centaurea* spp. (Thorp *et al.* 1983), *Cimicifuga arizonica* (Pellmyr 1985), *Corydalis caseana* (Maloof 2001), *Chrysothamnus* spp. (Thorp *et al.* 1983), *Cirsium* spp. (Thorp *et al.* 1983), *Cosmos* spp. (Thorp *et al.* 1983), *Dahlia* spp. (Thorp *et al.* 1983), *Delphinium nuttallianum* (Irwin and Maloof 2002), *Erica carnea* (Macfarlane and Patten 1997), *Erythronium grandiflorum* (Thomson 1986), *Foeniculum* spp. (Thorp *et al.* 1983), *Gaultheria shallon* (Thorp *et al.* 1983), *Geranium* spp. (Thorp *et al.* 1983), *Gladiolus* spp. (Thorp *et al.* 1983), *Grindelia* spp. (Thorp *et al.* 1983), *Haplopappus* spp. (Thorp *et al.* 1983), *Hedysarum alpinum* (Macior 1979), *Hypochoeris* spp. (Thorp *et al.* 1983), *Ipomopsis aggregata* (Irwin and Brody 1999), *Lathyrus* spp. (Thorp *et al.* 1983), *Linaria vulgaris* (Irwin and Maloof 2002), *Lotus* spp. (Thorp *et al.* 1983), *Lupinus monticola* (Bauer 1983), *Mentha* spp. (Thorp *et al.* 1983), *Medicago* spp. (Thorp *et al.* 1983), *Melilotus* spp. (Thorp *et al.* 1983), *Mertensia ciliata* (Bauer 1983), *Monardella* spp. (Thorp *et al.* 1983), *Nama* spp. (Thorp *et al.* 1983), *Origanum* spp. (Thorp *et al.* 1983), *Orthocarpus* spp. (Thorp *et al.* 1983),

Pedicularis capitata, *P. kanei*, and *P. langsdoorfii* (Macior 1978a), *Pedicularis groenlandica* (Macior 1968b), *Penstemon procerus* (Bauer 1983), *Phacelia* spp. (Thorp *et al.* 1983), *Prunus* spp. (Macfarlane and Patten 1997), *Raphanus* spp. (Thorp *et al.* 1983), *Rhododendron* spp. (Thorp *et al.* 1983), *Salix* spp. (Macfarlane and Patten 1997), *Salvia* spp. (Thorp *et al.* 1983), *Solidago* spp. (Thorp *et al.* 1983), *Symphoricarpos* spp. (Thorp *et al.* 1983), *Tanacetum* spp. (Thorp *et al.* 1983), *Taraxacum* spp. (Thorp *et al.* 1983), *Trifolium dasyphyllum* (Bauer 1983), *Trichostema* spp. (Thorp *et al.* 1983), *Trifolium* spp. (Thorp *et al.* 1983), and *Zea* spp. (Thorp *et al.* 1983).

C. Population Distribution and Status

According to Milliron (1971), the historic range of *B. occidentalis* was the west coast of North America from central California north to Alaska, east through Alberta and western South Dakota, and southward into Arizona and New Mexico (see Figure 7). U.S. states included in *B. occidentalis*' historic range are northern California, Oregon, Washington, Alaska, Idaho, Montana, western Nebraska, western North Dakota, western South Dakota, Wyoming, Utah, Colorado, northern Arizona, and New Mexico. Canadian provinces included in its historic range are Alberta, British Columbia, Saskatchewan, and the Yukon Territory. *B. occidentalis* was considered abundant in California (Thorp *et al.* 1983) and in the Pacific Northwest (Stephen 1957). See Appendix IC for a list of some of the *B. occidentalis* records from major museum collections.

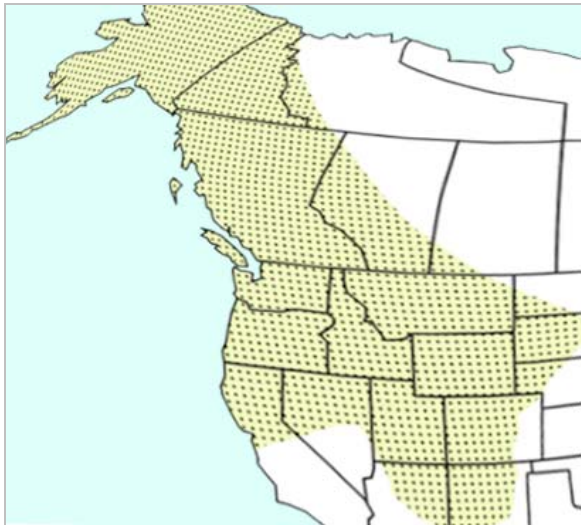


Figure 7. Historic distribution of *Bombus occidentalis*. Map is based on Milliron (1971).

In 2007, James Strange and his colleagues visited many historical *B. occidentalis* sites. They found *B. occidentalis* at approximately one quarter of the historical sites that were visited, including sites in Utah, northeastern California, southern Oregon, and Nevada (J. Strange, personal communication September, 2007; see Figure 8).

Since 1998, *B. occidentalis* has declined most dramatically from western and central California, western Oregon, western Washington, and British Columbia. Although absent from much of its former range, *B. occidentalis* is still found in isolated areas, primarily in

the Rocky Mountains. Below are findings from recent studies; table 5 summarizes many of these findings.

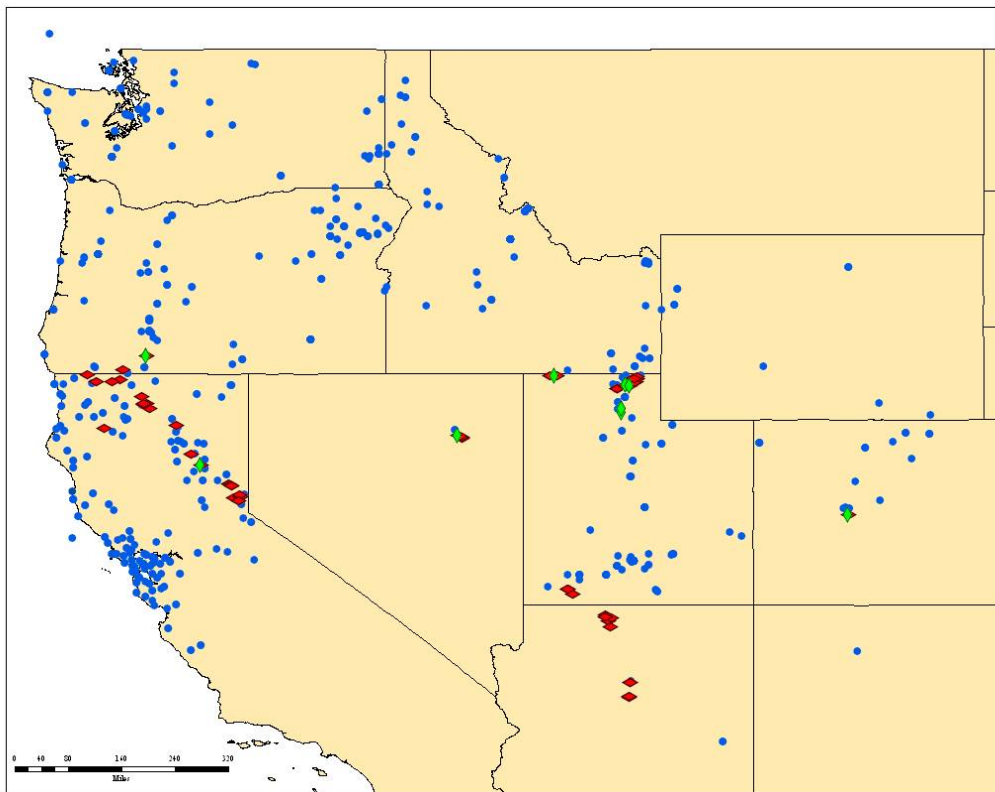


Figure 8. Blue dots indicate historical records of *B. occidentalis* from museum collections. The red diamonds indicate historic sites that were revisited in 2007 and *B. occidentalis* were not found. Green diamonds indicate historic *B. occidentalis* sites that were revisited in 2007 and *B. occidentalis* were found. Map courtesy of James Strange, USDA-ARS Pollinating Insects Research Unit, Logan, UT.

West coast of North America:

B. occidentalis was one of the most common bumblebees on the west coast until the mid 1990's (Rao and Stephen 2007). In Alaska, two specimens of *B. occidentalis* have been collected in the last seven years: in 2004 one was collected from the Kenai National Wildlife Refuge, and in 2001 one specimen was collected from the town of Soldotna (M. Bowser, personal communication, January 2008). A study in the early 1980's of bumble bees in British Columbia berry crops revealed that more than 30% of all bumble bees collected (192 out of 591) were *B. occidentalis* (Winston and Graf 1982). A more recent study in 2000 and 2001 of urban backyards in British Columbia revealed that only two out of 1,606 bumble bees collected, or 0.1%, were *B. occidentalis* (Tommasi *et al.* 2004). Although bumble bee species composition may vary between berry fields and urban backyards, *B. occidentalis* was previously common in urban areas (R. Thorp, personal communication, September 2008). In 2005, one queen was collected in Victoria, British Columbia (<http://bugguide.net/node/view/23813>).

A review of the Washington State University *B. occidentalis* collection revealed numerous *B. occidentalis* prior to 1998, and no *B. occidentalis* specimens from 1998 to 2007 (S. Jepsen, personal observation, March 2008, specimens on loan to W.P. Stephen). A review of *B. occidentalis* specimens from the Idaho State University collection revealed no *B. occidentalis* since 1999, and numerous specimens prior to 1999 (S. Jepsen, personal communication, March 2008, specimens on loan to W.P. Stephen). This observation is suggestive of a decline, but it is possible that collecting effort has diminished in these areas since the late 1990s.

Robbin Thorp has extensively searched several sites in southern Oregon and northern California where *B. occidentalis* used to be common. He has only found one *B. occidentalis* individual since 2002 (Thorp 2008). In yearly surveys of southern Oregon and northern California sites in which a total of 15,573 bumble bees were observed from 1998 to 2007, 102 *B. occidentalis* were observed in 1998, nine in 1999, one in 2000, one in 2001, one in 2002, and none in 2003, 2004, 2005, 2006, or 2007 (Thorp 2008, Figure 9). In 2008, a single *B. occidentalis* specimen was captured on Mt. Ashland in Oregon in a survey that included over 2,000 bees that were caught in blue vane traps (R. Thorp, personal communication, September 2008). An additional 2,000 bumble bees were examined foraging at flowers. No additional *B. occidentalis* were observed, indicating that although present, *B. occidentalis* is still extremely rare.

In the Willamette Valley of Oregon, researchers report that *B. occidentalis* was not seen from the summer of 1997 through 2005, then three *B. occidentalis* specimens were collected in 2006 and three more were collected in 2007 (Rao and Stephen 2007). In 2007, Chiho Kimoto collected over 20 *B. occidentalis* at The Nature Conservancy's Zumwalt Prairie Preserve in eastern Oregon; her advisor, Sandy DeBano, reports that the bees were identified by W.P. Stephen at Oregon State University. Dr. DeBano also notes that *B. occidentalis* were quite rare; they made up less than half of one percent of the relative abundance of all bumble bees collected (S. DeBano, personal communication, April 2008).

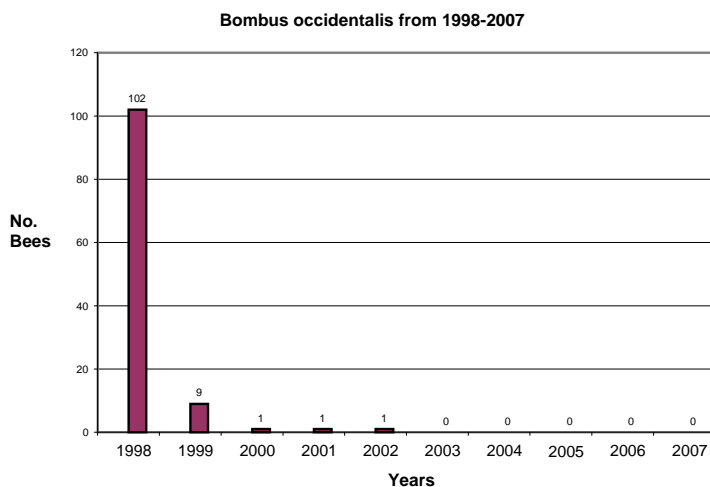


Figure 9. Number of *Bombus occidentalis* collected by Dr. Robbin Thorp at sites in southern Oregon and northern California from 1998-2007.

Historical records from within San Francisco, California revealed 105 *B. occidentalis* specimens in the collections of the California Academy of Sciences, revealing that *B. occidentalis* was commonly collected in San Francisco. Collections of 3,665 bumble bees in San Francisco in 2003 and 2004 revealed zero *B. occidentalis* (McFrederick and LeBuhn 2006). In addition, Thorp and colleagues collected 151 *B. occidentalis* in a wild park contiguous with San Francisco (San Bruno Mountain) in 1960. Revisiting the site just over 40 years later (2001 and 2002), he found no *B. occidentalis* (R. W. Thorp unpublished). Two additional years (2003 and 2004) of sampling at the same site by Q. S. McFrederick again confirmed the absence of *B. occidentalis* (McFrederick and LeBuhn 2006).

Rocky Mountains and the Intermountain West:

A collection of 3,586 bumble bee workers from 1997 to 2000 by Otterstatter, Whidden, and Owen in southern Alberta revealed that the relative abundance of *B. occidentalis* workers declined during the period from 1997 to 2000. The abundance of *B. occidentalis* workers relative to workers of other species of bumble bees in 1997 was 16.8%, in 1998 was 17.6%, in 1999 was 10.2%, and in 2000 was 9.9%. Dr. Otterstatter stated “I can say with certainty that *B. occidentalis* declined in abundance at my main study site (Barrier Lake) between 1997/98 and 1999/2000.” He also reported that “the relative abundance value of 9.9% for *B. occidentalis* workers at Barrier Lake during 2000 is certainly an overestimate; it took a far greater collecting effort to catch 10% *B. occidentalis* during 2000 than it did during 1999” (M. Otterstatter, personal communication, March 2008; data from 1997 and 1998 was also collected by T. Whidden and R. Owen). Dr. Ralph Cartar reports a similar decline in *B. occidentalis* in southern Alberta. In 1998, a study of bumble bees foraging on Moose Mountain revealed that 49 out of 581 bees, or 8.4%, were *B. occidentalis*. In contrast, in 2007 graduate student Danusha Foster collected only two *B. occidentalis* out of 91 total bees (or 2.2%) in an area that is 50 km SE of the 1998 study (R. Cartar, personal communication, April 2008). *B. occidentalis* is still consistently found at higher elevations in Colorado, although it may not be as common as it used to be (D. Inouye, personal communication, September 2007 and July 2008). In 2007, *B. occidentalis* was found in Japanese beetle trap contents from over a dozen locations in Utah and two traps in Spokane, WA (J. Strange personal communication, June 2008). In 2008, Dr. Strange and associates have captured *B. occidentalis* queens from two sites in northern Utah (J. Strange personal communication, June 2008).

Southwestern United States:

In Coconino County of northern Arizona, eighteen specimens of *B. occidentalis* were collected from 2000 to 2004 (L. Stevens, personal communication, February 2008).

Summary

B. occidentalis was once a common bumble bee that was widespread across 14 U.S. states and four Canadian provinces. The data and observations detailed above reveal that this species has undergone a dramatic decline across much of the western part of its range.

Surveys prior to 1999					Surveys between 1999-2008				
Region	Researcher(s) / Publication	Survey year(s)	Total # of bumble bees collected	Relative abundance of <i>B. occidentalis</i> in collection	Region	Researcher(s) / Publication	Survey year(s)	Total # of bumble bees collected	Relative abundance of <i>B. occidentalis</i> in collection
British Columbia (berry crops)	Winston & Graf 1982	1982	591	32%	British Columbia (urban backyards)	Tommasi <i>et al.</i> 2004	2000-2001	1,606	0.1%
Southern OR and Northern CA	Thorp 2008	1998	848	12.03%	Southern OR and Northern CA	Thorp 2008	1999	588	1.53%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2000	2,500	0.04%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2001	213	0.47%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2002	2,000	0.05%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2003	1,094	0%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2004	1,442	0%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2005	2,698	0%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2006	1,438	0%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp 2008	2007	1,418	0%
See above	See above	See above	See above	See above	Southern OR and Northern CA	Thorp (unpublished data)	2008	>4,000	~0.025%
Southern Alberta	Otterstatter, Whidden & Owen (pers. comm. March 2008)	1997	322 (workers only)	16.8%	Southern Alberta	Otterstatter, Whidden & Owen (pers. comm. March 2008)	1999	1,618 (workers only)	10.2%
Southern Alberta	Otterstatter, Whidden & Owen (pers. comm. March 2008)	1998	891 (workers only)	17.8%	Southern Alberta	Otterstatter, Whidden & Owen (pers. comm. March 2008)	2000	755 (workers only)	9.9%*
Moose Mountain, southern Alberta	Carter (pers. comm. April 2008)	1998	581	8.4%	50 km SE of 1998 Carter study site, southern Alberta	Foster (R. Carter, pers. comm. April 2008)	2007	91	2.2%
-	Abundant in historical collections of the California Academy of Sciences	-	-	-	San Francisco, California	McFrederick & LeBuhn 2006	2003-2004	6,665	0%

Table 5. Comparison of *B. occidentalis* relative abundance prior to 1999 and since 1999.

*M. Otterstatter stated that: “the relative abundance value of 9.9% for *B. occidentalis* workers at Barrier Lake during 2000 is certainly an overestimate; it took a far greater collecting effort to catch 10% *B. occidentalis* during 2000 than it did during 1999” (personal communication, March 2008).

VI. CURRENT AND POTENTIAL THREATS - SUMMARY OF FACTORS FOR CONSIDERATION

A. Spread of Diseases and Pests by Commercial Bumble Bee Producers

In North America, two bumble bee species have been commercially reared for pollination of greenhouse tomatoes and other crops: *B. occidentalis*, which is native to western North America and *B. impatiens*, which is native to eastern North America. Most commercial rearing for U.S. crops has occurred in the U.S. or Canada. However, between 1992 and 1994, queens of *B. occidentalis* and *B. impatiens* were shipped to European rearing facilities, where colonies were produced and then allowed by the Animal and Plant Health Inspection Service (USDA-APHIS) to be shipped from Europe back to the U.S. for commercial distribution (Flanders *et al.* 2003).

One of the authors of this review (RWT) has hypothesized that, while in European rearing facilities, these bumble bee colonies acquired a selectively virulent strain of *Nosema bombi* from the closely related and commercially reared European bumble bee *Bombus terrestris*. Thorp hypothesizes that this disease is the most probable cause for the recent declines of the three species of bumble bees in this status report and their close relative *Bombus franklini* (Thorp 2003; Thorp 2005; Thorp and Shepherd 2005). Other pests and diseases that could have been spread by commercial bumble bee producers and have led to a decline in these three species of bumble bees include *Crithidia bombi*, *Locustacarus buchneri*, and deformed wing virus.

Nosema bombi:

Nosema bombi is a microsporidian that infects bumble bees primarily in the malpighian tubules, but also in fat body, nerve cells, and sometimes the tracheae (Macfarlane *et al.* 1995). Colonies can appear to be healthy but still carry *N. bombi* (Ronny Larson 2007) and transmit it to other colonies. The effect of *N. bombi* on bumble bees varies from mild to severe (Macfarlane *et al.* 1995; Otti and Schmid-Hempel 2007, 2008; Ronny Larson 2007; Rutrecht *et al.* 2007).

The probable route of introduction and spread of the disease is as follows. Two main commercial producers, Koppert and BioBest, became involved in bumble bee production in North America in the early 1990's. Queens of both *B. occidentalis* and *B. impatiens* were shipped to European rearing facilities. Then, between 1992 and 1994, the Animal and Plant Health Inspection Service (USDA-APHIS) granted permission for *B. occidentalis* and the eastern *B. impatiens* (*Pyrobombus*) to be shipped from Europe back to the U.S. (Flanders *et al.* 2003). These colonies were likely produced in a rearing facility that also was rearing *B. terrestris*, a member of the subgenus *Bombus* and a close relative of the three species considered here. It is hypothesized that a virulent strain of *N. bombi* from *B. terrestris* spread to *B. impatiens* and *B. occidentalis* prior to their shipment back to the U.S. Colonies imported to commercial rearing facilities are typically subject to inspection, however, such checks often only include honey bee diseases as regulations are often copied from pre-existing honey bee regulations (Velthuis and van Doorn 2006). No precautions to prevent commercially reared colonies from interacting with wild populations were deemed necessary since they were being used in their areas of origin.

Bumble bee colonies can be infected with *N. bombi* and show no apparent symptoms, making it possible for apparently healthy colonies to carry and spread the pathogen. Because *N. bombi* can be present in areas throughout the bee body, surveys of *N. bombi* cannot be restricted to smears from the gut and Malpighian tubules or to fecal sampling of spores, which is a method commonly used (Ronny Larson 2007). Methods have recently been developed to detect *N. bombi* infections by PCR diagnosis, which provides a much more accurate picture of low-level infections (Klee *et al.* 2006).

Researchers at the University of Illinois at Urbana-Champaign have identified a microsporidium (*Nosema bombi*) in many North American bumble bees that is genetically identical to that found in European bumble bees (Illinois Natural History Survey Reports 2007). However, characterizing the geographic origins of different strains of *N. bombi* is complicated by the existence of multiple rRNA strains in single spores (O'Mahony *et al.* 2007). It is not presently clear whether this *Nosema* is an introduced species or if the pathogen occurs naturally in North American *Bombus* populations. Further testing will determine if this pathogen was recently spread to North American bumble bees (L. Solter, personal communication, March 2008).

N. bombi has been shown to spread between bumble bee species both in the lab and the wild. *N. bombi* isolated from commercial European *B. terrestris* colonies exported to Japan were found to infect two native Japanese bumble bees in lab trials (Niwa *et al.* 2004). *N. bombi* has been found in China in wild-caught *Bombus lucorum* and in queens of *Bombus terrestris* from New Zealand. *B. lucorum* are native to China and are closely related to the non-native *B. terrestris*, which have been imported from New Zealand into China for pollination (Jilian *et al.* 2005). *N. bombi* and other bumble bee pathogens have been shown to spread from areas housing greenhouses employing commercial bumble bees to nearby wild bumble bees (Colla *et al.* 2006). As bumble bees in greenhouses frequently forage outside the greenhouse (Whittington *et al.* 2004), it is likely that *N. bombi* could spread from commercial bumble bee colonies to wild populations through shared use of flowers. Such a spread of disease could potentially decimate wild populations of closely related bumble bee species.

In the mid-1990s, APHIS frequently issued courtesy permits for the interstate transport of bumble bees. In response to recommendations by bumble bee scientists, *B. impatiens* was only allowed to be distributed to eastern states and *B. occidentalis* only to western states, in order to try to keep each species within its respective native range (Flanders *et al.* 2003), and thus prevent the spread of exotic diseases to wild populations of bumble bees. However, in 1997, large scale commercial rearing companies began to experience problems with infection by *N. bombi* in *B. occidentalis* colonies (Flanders *et al.* 2003; Velthuis and van Doorn 2006). Supplies of *B. occidentalis* colonies were not able to meet the demand of greenhouse tomato and cranberry growers. In response to growing requests from western crop producers, APHIS decided to stop issuing all courtesy permits in 1998, leaving the matter of regulating interstate movement of bees up to individual state governments. This resulted in many growers bringing *B. impatiens* into western states for crop pollination (Flanders *et al.* 2003). Currently, the only western states that regulate the importation of *B. impatiens* are Oregon and California; California allows *B.*

impatiens to be transported into the state for greenhouse pollination, but not for open field pollination, whereas Oregon does not allow this species to come into the state.

Both Koppert and BioBest have discontinued their programs to rear *B. occidentalis*. *B. impatiens* colonies were found to be better adapted to greenhouse pollination than *B. occidentalis* (Whittington and Winston 2003).

The National Academy of Sciences National Research Council (NRC) report on the Status of Pollinators in North America states that the microsporidium *Nosema bombi* may be the primary factor responsible for the imminent extinction of *Bombus franklini* (another bumble bee in the subgenus *Bombus sensu stricto* that is closely related to *B. affinis*, *B. terricola*, and *B. occidentalis*). The NRC report reviews studies which suggest that when heavily infected commercial colonies come into contact with wild bumble bee populations, pathogens can be introduced or amplified in nearby wild populations of closely related species, potentially having negative impacts. The report also suggests that the disappearance of *B. occidentalis* from the western part of its range may be due to pathogen spillover from infected, commercially raised bumble bee colonies (National Research Council 2007).

Crithidia bombi:

The internal protozoan parasite, *Crithidia bombi*, could also be leading to the decline of *B. occidentalis*, *B. affinis* and *B. terricola*. *Crithidia bombi* has been shown to be present in higher frequencies in bumble bees near greenhouses where commercial colonies of *B. impatiens* are used than in bumble bees remote from these facilities (Colla *et al.* 2006). Wild bumble bees were found to have *C. bombi* infection rates as high as 47% near commercial greenhouses using bumble bees with the rates of infection for all bumble bee species decreasing with increased distance from the greenhouses (Otterstatter and Thompson 2008). Otterstatter and Thompson (2008) note that pathogen spillover from bumble bees in commercial greenhouses is likely contributing to the decline of wild North American bumble bees. *Crithidia bombi* has been shown to spread to new bumble bee hosts through shared use of flowers (Durrer and Schmid-Hempel 1994). *Crithidia bombi* has been shown to have detrimental effects on colony founding success of queens, the fitness of established colonies, as well as the survival and foraging efficiency of worker bumble bees (Brown *et al.* 2000, 2003; Otterstatter *et al.* 2005; Gegear *et al.* 2005, 2006).

Locustacarus buchneri:

Commercially raised bumble bee colonies can potentially spread the bumble bee tracheal mite *Locustacarus buchneri* to wild populations. Goka *et al.* (2001) found that commercially raised bumble bees had a higher rate of infestation by tracheal mites than wild bees (17 to 20% in commercially raised bees vs. 1 to 8% of wild bees). Although the means of mite dispersal are currently not well understood, tracheal mites could spread from commercial to wild colonies through drifting workers or contact on shared flowers. Bumble bees in the sub-genus *Bombus sensu stricto* may be more susceptible to tracheal mite infestation than other bumble bees. Otterstatter and Whidden (2004) found that the bumble bee tracheal mite (*L. buchneri*) was most prevalent in bumble bee species

belonging to the subgenus *Bombus* sensu stricto.

Deformed wing virus:

Commercial bumble bee rearing may also provide an opportunity for the transmission of honey bee diseases to bumble bees. Commercial bumble bee producers sometimes introduce young honey bees to nesting bumble bee queens to stimulate them to begin egg-laying. This practice exposes bumble bees to diseases carried by the honey bees. Deformed wing virus (DWV), a honey bee pathogen that results in crippled wings, was thought to be specific to honey bees. However, starting in 2004, dead bumble bee queens with crumpled, vestigial wings were found in European commercial bumble bee breeding operations at a frequency of around 10% (Genersch *et al.* 2006). DWV is pathogenic to at least two bumble bee species (*B. terrestris* and *B. pascuorum*), causing wing deformity similar to clinically DWV-infected honey bees (Genersch *et al.* 2006). The symptoms of DWV have also been observed in commercially raised *B. impatiens* colonies in North America (E. Evans personal observation, March 2008). Since bees exhibiting symptoms of DWV are unable to forage, DWV infection has the potential to negatively impact the success of colonies. Honey bees have also been shown to be possible vectors for the trypanosomatid *Crithidia bombi* (Ruiz-González and Brown 2006). *C. bombi* does not infect honey bees but they can carry this parasite and possibly spread it to bumble bees.

Use of commercial bumble bee colonies in scientific studies:

Commercially produced bumble bee colonies that were potential carriers of pests or disease were distributed through much of North America. In addition to being used for commercial pollination, *B. occidentalis* colonies were used for field research between 1992 and 2000 in CA, WA, and Alberta (Macfarlane *et al.* 1994; Mayer *et al.* 1994; Richards and Myers 1997; Macfarlane and Patten 1997; Mayer and Lunden 1997, 2001; Thomson 2004, 2006; Thorp unpublished). Although *B. impatiens* belongs to a distantly related subgenus of bumble bees (*Pyrobombus*) and does not appear to be undergoing a decline, it could serve as a carrier of pests or diseases (such as *Nosema bombi*) which would explain the parallel declines in eastern North American species of the subgenus *Bombus*. Commercial colonies of *B. impatiens* have been distributed throughout eastern North America from the mid-1990s until the present day. *B. impatiens* was used for field research between 1995 and 2000 in Maine, Minnesota, Wisconsin, and Quebec (Stubbs and Drummond 1997; Meisels and Chaisson 1997; Evans 2001; Evans and Spivak 2006), and possibly in other areas as well. Thus, the potential for spread of an exotic strain of *Nosema* or other disease organisms through wild populations of the subgenus *Bombus* in North America is well supported.

B. Inadequacy of Existing Regulatory Mechanisms

Currently bumble bees have no substantive protection for habitat or take under federal law or individual state's laws. There are no current regulations that limit the interstate transport of bumble bees (Flanders 2003). Current law also allows the transport of two species of bumble bees from Canada (*B. impatiens* and *B. occidentalis*) to all U.S. states except Hawaii under the Honeybee Act § 322.4 and § 322.5, which is enforced by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS). While importation of bumble bees from other countries is not currently allowed, if a

request is made to APHIS, APHIS will evaluate the request and can decide to allow or disallow importation (§ 322.12 of the Honeybee Act). Both *B. occidentalis* and *B. terricola* have parts of their ranges outside of the native range of *B. impatiens*. Interstate and international transport of bumble bees, such as *B. impatiens*, to areas where they do not normally occur, may increase the exposure of wild bumble bees to exotic pathogens and destroy the isolated populations of *B. occidentalis* and *B. terricola* that remain. Since these commercially raised bees may carry exotic diseases, they are a potential threat even within their native range, particularly to populations that are in decline such as *B. affinis*.

APHIS has the ability to establish a domestic quarantine of bumble bees, in order to stop the spread of a pathogen that may be causing the extinction of North American bumble bees, although they have not yet done this and have said that they are not likely to do this (W. Wehling and C. Stewart, personal communication, April 2008).

C. Habitat Alteration

Bumble bee populations are subject to threat by many kinds of habitat alterations which may destroy, fragment, degrade, or reduce their food supplies (flowers that produce the nectar and pollen they require), nest sites (e.g. abandoned rodent burrows or undisturbed grass), and hibernation sites for over-wintering mated queens. Fragmentation of bumble bee populations can result in problems including inbreeding depression (Darvill *et al.* 2006; Ellis *et al.* 2006) and an increased risk of extinction due to demographic stochasticity. Threats that alter habitat required by bumble bees include agricultural intensification, livestock grazing, urban development, and fragmentation of landscapes.

Agricultural intensification:

Increases in farm size and operating efficiency have led to loss of pollinator friendly hedge rows, weed cover, and legume pastures through more modern practices including more effective land leveling, irrigation, tilling, and pesticide and fertilizer usage.

Although most *Bombus* *sensu stricto* nest underground, nests are sometimes located above the ground in clumps of grass (Macfarlane *et al.* 1994). Bumble bee nests that are formed above ground are at risk of being destroyed by farm machinery (Goulson 2003). Hines and Hendrix (2005) found that bumble bee diversity in Iowa prairies was linked to floral abundance and the presence of grasslands in the surrounding landscape, both of which are negatively affected in many agricultural landscapes. In Ireland, England, and central Europe, agricultural intensification is deemed responsible for recent declines of bumble bee species (Williams 1986; Carvell *et al.* 2006; Diekötter *et al.* 2006; Fitzpatrick *et al.* 2007; Kosior *et al.* 2007; Goulson *et al.* 2008). The decline of bumble bees in Illinois was found to coincide with a period of major agricultural intensification in the Midwest, indicating that agricultural intensification may have led to the local extirpation and decline of Illinois bumble bees (Grixti *et al.* in press).

Livestock grazing:

Livestock grazing may adversely impact bumble bee populations by (1) depleting bumble bee food sources (Morris 1967; Sugden 1985; Carvell 2002; Kruess and Tschardtke 2002a, 2002b; Vazquez and Simberloff 2003; Hatfield and LeBuhn 2007), (2) trampling of above ground nesting sites (Sugden 1985), and (3) negatively impacting nesting

rodents which in turn reduces the number of nest sites available for bumble bees. Livestock grazing has differing impacts on flora and fauna based on the type, habitat, intensity, timing, and length of livestock grazing (Gibson *et al.* 1992; Sjodin 2007), but there is potential for a negative impact on bee populations with many grazing situations.

Urban development:

While urban gardens and parks may provide habitat for some pollinators including bumble bees (Frankie *et al.* 2005; McFrederick and LeBuhn 2006), they tend not to support the species richness of bumble bees that can be found in nearby wild landscapes (R. Thorp personal observation) or that was present historically (McFrederick and LeBuhn 2006). There is indication that human built structures such as roads and railroads fragment plant populations and restrict bumble bee movement (Bhattacharya *et al.* 2003).

Habitat fragmentation:

Agricultural intensification, livestock grazing, urban development, as well as other factors, can lead to the fragmentation of bumble bee habitat into pieces that are too small or too distant to support diverse bumble bee communities (Goulson *et al.* 2008). Fragmented habitats may not support healthy metapopulation structures and may eliminate or decrease source populations of bumble bees for recolonization (National Research Council 2007).

Fire suppression:

In pre-settlement times, meadows were maintained by periodic fires that helped curtail conversion to forest by restricting the establishment of trees along forested edges with grasslands. Fire suppression, and resultant forest encroachment into occupied meadow patches, reduces meadow habitats available to bumble bees.

D. Pesticides

Insecticides:

Insecticide applications may threaten populations of bumble bees of the subgenus *Bombus* sensu stricto. The National Academy of Science National Research Council's report on the Status of Pollinators in North America notes that bumble bees can be negatively affected by many pesticides, but the lack of large scale monitoring of bumble bees makes the scope of the problem difficult to fully determine. The report also points out that ground-nesting bumble bees are uniquely susceptible to pesticides that are used on lawns or turf (National Research Council 2007). Foraging bees are poisoned by pesticides when they absorb the fast-acting toxins through their integument (the outer "skin" that forms their exoskeleton), drink contaminated nectar, or gather pesticide-covered pollen or micro-encapsulated poisons. Pesticide drift from aerial spraying can kill 80% of foraging bees close to the source and drift can continue to be dangerous for well over a mile (Johansen and Mayer 1990). Insecticides applied in the spring, when bumble bee queens are foraging and colonies are small, are likely to have a more significant effect on bumble bee populations (Goulson *et al.* 2008). The relatively recent and increased use of persistent neonicotinoid pesticides, known to be highly toxic to bees, may pose an increased threat to bumble bees in the subgenus *Bombus* (Colla and Packer 2008).

Insecticides are used in wild lands, agricultural landscapes, and urban areas to control both native and non-native pest species. In forested areas insecticides have been used to control defoliators such as tussock moth, gypsy moth, and spruce budworm. In New Brunswick, Canada, bumble bee populations declined drastically when exposed to fenitrothion (reviewed in Kevan and Plowright 1995) resulting in reduced pollination of nearby commercial blueberries and other plants such as orchids and clovers (Kevan 1975; Plowright *et al.* 1978, 1980). Organophosphate, carbamate, and pyrethroid insecticides have been associated with bee poisonings in food crops (Johansen 1977; Kearns *et al.* 1998). Bumble bee deaths have been reported after pesticide applications to oil rape seed and field bean crops (Thompson and Hunt 1999; Thompson 2001). Bumble bees also are at risk from insecticides used for turf management in golf courses and urban parks (Gels *et al.* 2002). In Europe, the recent declines in bumble bees have been partially attributed to the use of pesticides (Williams 1986; Thompson and Hunt 1999; Rasmont *et al.* 2006).

Since males and queens are produced at the end of the colony cycle, even sub-lethal doses of pesticides can have substantial adverse effects on subsequent generations. Bees exposed to pesticides outside the nest may have trouble navigating their way back to the nest after foraging, or they may be unable to fly at all (Johansen and Mayer 1990). The use of Spinosad, a commonly used insect neurotoxin, has led to workers with reduced foraging efficiency when bumble bee larvae are fed with pollen containing this pesticide (Morandin *et al.* 2005). In an examination of the effect of chitin synthesis inhibitors on *Bombus*, Mommaerts *et al.* (2006) found that even at very low concentrations, diflubenzuron and teflubenzuron increased egg mortality and removal of larvae. Bumble bee workers exposed to low levels of Imidacloprid show reduced pollen consumption and ovarian development (Colla and Packer 2008).

Increasing numbers of insecticidal transgenic plants are being used to control pest species, and the effect of most of these transgenic plants on bumble bees is not known (Malone and Pham Delègue 2001). However, there is evidence of negative effects on bumble bees of two compounds that are produced in transgenic plants; the soybean trypsin inhibitor (a protease inhibitor) and *Galanthus nivalis* agglutinin (a lectin) have been shown to reduce bumble bee longevity and reproduction when administered experimentally (Babendreier *et al.* 2008). The amount of transgene product expressed in pollen and nectar is still unknown, so it is difficult to determine the impact of these products on bumble bees in the wild.

Herbicides:

Herbicides can be a valuable tool for the control of invasive weed species. However, the use of broad-spectrum herbicides to control weeds can indirectly harm pollinators by decreasing the usability of habitat for pollinators through removal of flowers that provide pollen and nectar for existing populations (Williams 1986; Shepherd *et al.* 2003). Just as pollinators can influence the plant community, changes in vegetation can have an impact on pollinators (Kearns and Inouye 1997).

The broadcast application of a non-selective herbicide can indiscriminately reduce floral resources, host plants, and nesting habitat (Smallidge and Leopold 1997). Bumble bees require consistent sources of nectar, pollen, and nesting material during times adults are active, typically from mid-February to late September in temperate areas. Such a reduction in resources could cause a decline in bumble bee reproductive success and/or survival rates. Kevan (1999) found that herbicides reduced Asteraceae and Lamiaceae flowers in France, contributing to a decline in bumble bee populations. Kevan (1999) also found that herbicide applications have reduced the reproductive success of blueberry pollinators by limiting alternative food sources that can sustain the insects when the blueberries are not in bloom. Kearns *et al.* (1998) state “herbicide use affects pollinators by reducing the availability of nectar plants. In some circumstances, herbicides appear to have a greater effect than insecticides on wild bee populations... Some of these bee populations show massive declines due to the lack of suitable nesting sites and alternative food plants.”

E. Invasive Species

Invasion and dominance of native grasslands by exotic plants is a widespread problem (Warren 1993; Schultz 1998), and has likely occurred within the ranges of declining members of the subgenus *Bombus*. Introduced plants could threaten these bumble bees by directly competing with their food plants.

Honey bees (*Apis mellifera*) are not native to North America. The European honey bee was introduced to eastern North America in the early 1620's and into California in the early 1850's. It has long been assumed, but difficult to demonstrate, that honey bees have a negative impact on native bees through competition for floral resources (Sugden *et al.* 1996; Butz Huryn 1997). Recently, Thomson (2004, 2006) conducted competition experiments on *B. occidentalis* colonies placed at three distances from introduced honey bee hives. Thomson found decreased foraging activity, especially for pollen, and lowered reproductive success in *Bombus* colonies nearest the *Apis* hives. Evans (2001) found the same results in a similar study with *B. impatiens* colonies in Minnesota. However, honey bees have been in eastern North America for over 350 years and in the west for more than 150 years without noticeable declines in bumble bee populations over large portions of their ranges. It is likely that the effects noted by Thomson (2004, 2006) and Evans (2001) are local in space and time and are most pronounced where floral resources are limited and large numbers of commercial honey bee colonies are introduced. Due consideration should be given to when, where, and how many honey bee colonies are moved into areas with sensitive bumble bee populations.

Although honey bees may not pose a significant threat to bumble bee populations through competition for floral resources in most cases, honey bees may threaten bumble bee populations through carrying and spreading pests and diseases to which bumble bees are susceptible. The invasive pest, the small hive beetle (*Aethina tumida*) was introduced to the United States in the late 1990's (Elzen *et al.* 1999). While honey bees are the small hive beetle's primary host, the beetle has been shown to also infest and cause damage in bumble bee colonies (Ambrose *et al.* 2000; Spiewok and Neumann 2006). The infestation rate of small hive beetles in bumble bee colonies is not currently known. Small hive

beetles use commercial honey bee colonies as hosts, and continue to spread throughout North America as commercial honey bees are transported for crop pollination. Small hive beetles have a great destructive capability and could cause great harm to native bumble bee populations.

Although most honey bee diseases are specific to honey bees, there is evidence of honey bees being carriers for bumble bee diseases, as well as there being the possibility of shared disease between honey bees and bumble bees. Honey bees are possible vectors for the trypanosomatid *Crithidia bombi* (Ruiz-González and Brown 2006) although honey bees are not infected by this gut parasite. Deformed wing virus (DWV), a honey bee pathogen that results in crippled wings, was thought to be specific to honey bees. However, there is evidence of this disease in European commercial bumble bee breeding operations (Genersch *et al.* 2006). Although commercial bumble bee rearing operations are the likely cause of the spread of DWV to bumble bees, honey bees have the potential to spread this disease and possibly others to wild bumble bee populations through contact at shared floral resources.

There is potential for non-native commercially raised bumble bees to naturalize and out-compete native bumble bees for limited resources such as nesting sites and forage. A study comparing reproductive output of native Japanese bumble bees with non-native *B. terrestris* colonies, founded by bees that had escaped from commercially produced colonies, found *B. terrestris* to have over four times the reproductive output of native Japanese bumble bees (Matsumura *et al.* 2004). A study in England comparing the nectar-foraging and reproductive output of a native subspecies of *B. terrestris* with commercially raised *B. terrestris* colonies found that the commercially raised colonies had higher nectar-foraging rates and greater reproductive output (Ings *et al.* 2006). Commercial bumble bee producers have likely selected for colonies that are highly productive to ensure strong colony populations for use in pollination. While this is a desirable quality for commercial rearing, it could prove to aid invasion of non-native species, subspecies, or varieties of bumble bees that would outcompete native bumble bee populations.

F. Other Threats

Increased inbreeding and haplodiploidy:

Bumble bees may be particularly susceptible to inbreeding due to low effective population size (Packer and Owen 2001). As with all other hymenopterans, their sex determination system is haplodiploidy. The sex of offspring is determined by whether or not the egg is fertilized. Unfertilized, or haploid, eggs become males and fertilized, or diploid, eggs become females. This sex determination system may result in lower levels of genetic diversity than diploid-diploid sex determination. Some bumble bees have been found to have particularly low levels of genetic diversity (Darvill *et al.* 2006; Ellis *et al.* 2006). Inbreeding depression has been shown to negatively affect bumble bee colony size (Herrmann *et al.* 2007), a key factor in a colony's reproductive success. Low genetic diversity may also increase the risks these bees face from threats such as parasites, diseases, and habitat loss. In haplodiploid organisms, such as bumble bees, low population levels and resulting inbreeding depression may also increase the risk of

population extinction by resulting in sterile diploid male production (Zayed and Packer 2005).

Bumble bees have many natural enemies including spiders, mites, flies, wasps, fungi, and diseases (Macfarlane *et al.* 1995). The impact of these natural enemies on bumble bee colony success varies depending on their prevalence. The prevalence and distribution of these natural enemies is not known for most of North America. When populations are very small, perhaps due to other factors, the impact of natural enemies would be heightened.

Climate change:

Global climate change will likely bring northward recession of the cold adapted species of bumble bees and expansion of ranges of warmer adapted species. Similar changes have been observed in other species of insects (reviewed in National Research Council 2007). Increased variability in the climate could also cause declines in an even broader range of species (Williams *et al.* 2007). Kirilenko and Hanley (2007a, 2007b) combine the results of four models to predict how climate change will impact *Bombus terricola*. Their models indicate that this bee will shift its range northward by approximately 220 km by 2030, 550 km by 2050, and 980 km by 2080. They predict that the range of *Bombus moderatus* (= *lucorum*), also in the subgenus *Bombus* sensu stricto, will shrink by 42%. They predict that *Bombus pensylvanicus* will expand its range by 16%.

Localized studies in the eastern U.S. have shown that some plants are flowering earlier than they were in the past, presumably due to climate change (Abu-Asab *et al.* 2001; Primack *et al.* 2004). Other studies have demonstrated changes in pollinator phenology correlated with regional changes in temperature (Roy and Sparks 2000; Forister and Shapiro 2003); if the phenology of plants and their pollinators do not change synchronously, it is possible that plant-pollinator relationships will be disrupted (National Research Council 2007).

An increase in atmospheric CO₂ from global climate change may alter plant nectar production, which could negatively impact bumble bees (reviewed by Davis 2003). An additional impact of climate change, increased amounts of UV-B radiation from a reduction in ozone, could delay flowering in plants and reduce the amount of flowers that plants produce (National Research Council 2007). These impacts could have negative effects on bumble bees.

Air pollution:

Air pollution destroys volatile hydrocarbons released from flowers that serve as signals to potential pollinators (McFrederick *et al.* 2008). Increases in air pollutants such as ozone may therefore interfere with the foraging efficiency of pollinators, especially in fragmented landscapes.

VII. CONCLUSION

There are a number of threats facing bumble bees, any of which may be leading to the decline of these species. The major threats to bumble bees include: spread of pests and

diseases by the commercial bumble bee industry, other pests and diseases, habitat destruction or alteration, pesticides, invasive species, natural pest or predator population cycles, and climate change. In the case of these bumble bees, several lines of evidence implicate introduced disease as the most likely cause of the declines of *Bombus* sensu stricto in North America. Firstly, the fact that other bumble bee species persist and thrive in areas where members of the subgenus *Bombus* sensu stricto in North America are declining suggests a more specific cause for vulnerability of this particular subset of our bumble bee fauna. Secondly, instead of a gradual decline over decades, as has been documented with British bumble bee populations (Williams *et al.* 2007), these bumble bees went from being widespread and commonly found to rare or absent within a relatively short period of time (about 7-10 years) throughout much or all of their previous ranges. A third factor indicating disease is the timing of the declines. The earliest declines were observed with *B. occidentalis* in western North America in the late 1990s; this is the same time that commercially raised *B. occidentalis* populations were exhibiting problems with *Nosema bombi* (Velthuis and van Doorn 2006). Several years later, scientists began to notice *B. affinis* and *B. terricola* populations declining in eastern North America. The fact that the bumble bees in decline are all closely related suggests that there could be genetic susceptibility to certain disease strains exhibited by bumble bees in the subgenus *Bombus* sensu stricto, or shared behavioral traits that increase their susceptibility to certain pests or parasites (Otterstatter and Whidden 2004). Declines from threats other than disease that are listed in this review would have likely impacted species across a broader range of bumble bee subgenera (Williams *et al.* 2007). Recent discoveries of isolated populations may indicate the existence of remnant populations of bumble bees that were either not exposed to the disease through geographic isolation or were resistant to the disease.

The most likely cause of introduction and spread of the disease is international and interstate transport of bumble bees by the commercial bumble bee rearing industry. APHIS currently regulates international transport of bumble bees, with the exception of transport between the U.S. and Canada (which allows the unregulated transfer of two species of bumblebees). However, there are no current regulations that limit the interstate transport of bumble bees. If APHIS established a domestic quarantine of bumble bees, they would be taking an important step towards stopping the spread of a pathogen that may be causing the extinction of North American bumble bees.

It is likely that other potential threats, including habitat destruction, pesticides, invasive species, and climate change, have contributed to the severity of the declines in *Bombus* sensu stricto. Populations under stress from these factors are more susceptible to severe population fluctuations. With an exotic disease as the likely underlying cause, these species, already under the strain of habitat loss, pesticide exposure, and climate change, are being pushed to the brink of extinction.

Most of the current information is based on literature records and some museum records (Appendix IA, B and C) for the bumble bees of concern in this review. In the future, assembly data from all major museum collections containing bumble bees would enhance our knowledge of historical distributions, relative abundances, flower records, and other

ecological data associated with museum specimens. Dr. Strange and colleagues have databased several thousand historic records of *B. occidentalis* from twelve museum collections in a continuing effort to understand the specific historic range and site characteristics and to guide current sampling efforts. Dr. Cameron and colleagues are in the process of databasing thousands of records of eastern bumble bees, including *B. terricola* and *B. affinis*. An itemized list of museum collections known and expected to have significant collections of bumble bees is in Appendix II.

VIII. LITERATURE CITED

- Abu-Asab, M. S., P. M. Peterson, S. G. Shetler, and S. S. Orli. 2001. Earlier plant flowering in spring as a response to global warming in the Washington, DC, area. *Biodiversity Conservation* 10: 597-612.
- Ambrose, J. T., M. S. Stanghellini, and D. I. Hopkins. 2000. A scientific note on the threat of small hive beetles (*Aethina tumida* Murray) to bumble bee (*Bombus* spp.) colonies in the United States. *Apidologie* 31: 455-456.
- Babendreier, D., B. Reichhart, J. Romeis, and F. Bigler. 2008. Impact of insecticidal proteins expressed in transgenic plants on bumblebee microcolonies. *Entomologia Experimentalis et Applicata* 126: 148-157.
- Banda, H. J., and R. J. Paxton. 1991. Pollination of greenhouse tomatoes by bees. *Acta Horticulturae* 288: 194-198.
- Batra, S. W. T. 1993. Male-fertile potato flowers are selectively buzz-pollinated only by *Bombus terricola* Kirby in upstate New York. *Journal of the Kansas Entomological Society* 66: 252-254.
- Bauer, P. J. 1983. Bumblebee pollination relationships on the Beartooth Plateau tundra of southern Montana. *American Journal of Botany* 70: 134-144.
- Bhattacharya, M., R. B. Primack, and J. Gerwein. 2003. Are roads and railroads barriers to bumblebee movement in a temperate suburban conservation area? *Biological Conservation* 109: 37-45.
- Biesmeijer, J. C., S. P. M. Roberts, M. Reemer, R. Ohlemüller, M. Edwards, T. Peeters, A. P. Schaffers, S. G. Potts, R. Kleukers, C. D. Thomas, J. Settele, and W. E. Kunin. 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313: 351-354.
- Bequaert, J. 1920. Hymenoptera collected near Boston, Mass., with description of a variety of *Bombus affinis*. *Psyche* 27: 6-12.
- Brown, M. J. F., R. Loosli, and P. Schmid-Hempel. 2000. Condition-dependent expression of virulence in a trypanosome infecting bumblebees. *Oikos* 91: 421-427.

- Brown, M. J. F., R. Schmid-Hempel, and P. Schmid-Hempel. 2003. Strong context-dependent virulence in a host-parasite system: reconciling genetic evidence with theory. *Journal of Animal Ecology* 72: 994-1002.
- Buchmann, S. L. 1983. Buzz pollination in angiosperms, p. 73-113. *In* C. E. Jones and R. J. Little, (eds.), *Handbook of Experimental Pollination Biology*, Van Nostrand Reinhold, New York, NY.
- Burns, I. 2004. Social development and conflict in the North American bumblebee *Bombus impatiens* Cresson. U of MN. Ph.D. Thesis.
- Butz Huryn, V. 1997. Ecological impacts of introduced honey bees. *Quarterly Review of Biology*. 72: 275-297.
- Cameron, S. A., H. M. Hines, and P. H. Williams. 2007. A comprehensive phylogeny of the bumble bees (*Bombus*). *Biological Journal of the Linnean Society* 91: 161-188.
- Cane, J. H. and D. Schiffhauer. 2003. Dose-response relationships between pollination and fruiting refine pollinator comparisons for cranberry (*Vaccinium macrocarpon*). *American Journal of Botany* 90: 1425-1432.
- Caron, D. M., R. C. Lederhouse, and R. A. Morse. 1975. Insect pollinators of onion in New York State. *HortScience* 10: 273-274.
- Carvell, C. 2002. Habitat use and conservation of bumblebees (*Bombus* spp.) under different grassland management regimes. *Biological Conservation* 103: 33-49.
- Carvell, C., D. B. Roy, S. M. Smart, R. F. Pywell, C. D. Preston, and D. Goulson. 2006. Declines in forage availability for bumblebees at a national scale. *Biological Conservation* 132: 481-489.
- Colla, S. R., M. C. Otterstatter, R. J. Gegear, and J. D. Thomson. 2006. Plight of the bumblebee: pathogen spillover from commercial to wild populations. *Biological Conservation* 129: 461-467.
- Colla, S. R. and L. Packer. 2008. Evidence for the decline of Eastern North American Bumble Bees, with special focus on *Bombus affinis* Cresson. *Biodiversity and Conservation* 17: 1379-1391.
- Corbet, S. A., M. Fussell, R. Ake, A. Fraser, C. Gunson, A. Savage, and K. Smith. 1993. Temperature and the pollinating activity of social bees. *Ecological Entomology* 18:17-30.
- Costelloe, B. H. 1988. Pollination ecology of *Gentiana andrewsii*. *Ohio Journal of Science* 88: 132-138.
- Cresson, E. T. 1863. List of the North American species of *Bombus* and *Apathus*.

Proceedings of the Entomological Society of Philadelphia 2: 83-116.

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

Davies, J. L. 1995. Caged almond pollination by bumble bees (*Bombus occidentalis*). MS Thesis, California State University, Chico. 41 pp.

Davis, A. R. 2003. Influence of elevated CO₂ and ultraviolet-B radiation levels on floral nectar production: a nectary-morphological perspective. *Plant Systematics and Evolution* 238: 169-181.

Diekotter, T., K. Walther-Hellwig, M. Conradi, M. Suter, and R. Frankl. 2006. Effects of landscape elements on the distribution of the rare bumblebee species *Bombus muscorum* in an agricultural landscape. *Biodiversity and Conservation* 15: 57-68.

Dieringer, G. 1982. The pollination ecology of *Orchis spectabilis* L. (Orchidaceae). *Ohio Academy of Science* 82: 218-225.

Durrer, S. and P. Schmid-Hempel. 1994. Shared use of flowers leads to horizontal pathogen transmission. *Proceedings of the Royal Society: Biological Sciences* 258: 299-302.

Ellis, J. S., M. E. Knight, B. Darvill, and D. Goulson. 2006. Extremely low effective population sizes, genetic structuring and reduced genetic diversity in a threatened bumblebee species, *Bombus sylvarum* (Hymenoptera: Apidae). *Molecular Ecology* 15: 4375-4386.

Elzen, P. J., J. R. Baxter, D. Westervelt, C. Randall, K. S. Delaplane, F. A. Eischen, L. Cuffs, and W. T. Wilson. 1999. Field control and biology studies of a new pest species, *Aethina tumida* Murray (Coleoptera: Nitidulidae), attacking European honey bees in the Western Hemisphere. *Apidologie* 30: 361-366.

Evans, E. C. 2001. Competition between European honey bees and native bumblebees: resource overlap and impact on reproductive success. Master's Thesis, University of Minnesota.

Evans, E. C. and M. Spivak. 2006. Effects of honey bee (Hymenoptera: Apidae) and bumble bee (Hymenoptera: Apidae) presence on cranberry (Ericales: Ericaceae) pollination. *Journal of Economic Entomology* 99: 614-620.

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

Fitzpatrick, U., T. E. Murray, R. J. Paxton, J. Breen, D. Cotton, V. Santorum, and M. J. F. Brown. 2007. Rarity and decline in bumblebees: a test of causes and correlates in the Irish fauna. *Biological Conservation* 136: 185-194.

Flanders, R. V., W. F. Wehling, and A. L. Craghead. 2003. Laws and regulations on the import, movement and release of bees in the United States. pp. 99-111. *In* K. Strickler and J. H. Cane (eds.) *For Nonnative Crops, Whence Pollinators of the Future?* Thomas Say Publications in Entomology: Proceedings. Entomological Society of America, Lanham, MD.

Forister, M. L. and A. M. Shapiro. 2003. Climatic trends and advancing spring flight of butterflies in lowland California. *Global Change Biology* 9: 1130-1135.

Frankie, G. W., R. W. Thorp, M. Schindler, J. Hernandez, B. Ertter, and M. Rizzardi. 2005. Ecological patterns of bees and their host ornamental flowers in two northern California cities. *Journal of the Kansas Entomological Society* 78: 227-246.

Franklin, H. J. 1913. The Bombidae of the New World. *Transactions of the American Entomological Society* 38: 177-486.

Franzen, P. 1993 (unpublished). Field study of native bees (bumblebees) *Bombus* species. Fermilab, Batavia, Illinois.

Frost, S. W. 1965. Insects and pollinia. *Ecology* 46: 556-558.

Fye, R. E. and J. T. Medler. 1954. Spring emergence and floral hosts of Wisconsin bumblebees. *Transactions of the Wisconsin Academy of Science, Arts and Letters* 43: 75-82.

Galen, C. and R. C. Plowright. 1985. Contrasting movement patterns of nectar-collecting and pollen-collecting bumble bees (*Bombus terricola*) on fireweed (*Chamaenerion angustifolium*) inflorescences. *Ecological Entomology* 10: 9-17.

Gegear, R. J., M. C. Otterstatter, and J. D. Thomson. 2005. Does parasitic infection impair the ability of bumblebees to learn flower-handling techniques? *Animal Behaviour* 70: 209-215.

Gegear, R. J., M. C. Otterstatter, and J. D. Thomson. 2006. Bumble-bee foragers infected by a gut parasite have an impaired ability to utilize floral information. *Proceedings of the Royal Society B*. 273: 1073-1078.

Gels, J., D. W. Held, and D. A. Potter. 2002. Hazards of insecticides to the bumble bees *Bombus impatiens* (Hymenoptera: Apidae) foraging on flowering white clover in turf. *Journal of Economic Entomology* 95: 722-728.

Genersch, E., C. Yue, I. Fries, and J. R. de Miranda. 2006. Detection of Deformed wing

- virus, a honey bee viral pathogen, in bumble bees (*Bombus terrestris* and *Bombus pascuorum*) with wing deformities. *Journal of Invertebrate Pathology* 91: 61-63.
- Gibson, C., V. Brown, L. Losito, and G. McGavin. 1992. The response of invertebrate assemblies to grazing. *Ecography* 15: 166-176.
- Giles, V. and J. S. Ascher. 2006. A Survey of Bees of the Black Rock Forest Preserve, New York (Hymenoptera: Apoidea). *Journal of Hymenoptera Research* 15: 208-231.
- Goka, K., K. Okabe, M. Yoneda, and S. Niwa. 2001. Bumblebee commercialization has caused international migration of parasitic mites. *Molecular Ecology* 10: 2095-2099.
- Goulson, D. 2003. *Bumblebees, Their Behaviour and Ecology*. Oxford University Press, Oxford.
- Goulson, D., G. C. Lye, and B. Darvill. 2008. Decline and conservation of bumble bees. *Annual Review of Entomology* 53: 191-208.
- Greene, J. W. 1858. Descriptions of several new hymenopterous insects from the north west coast of America. *Annals of Lyceum of Natural History of New York* 7: 11-12.
- Grixti, J. C., L. T. Wong, S. Cameron, and C. Favret. Decline of bumble bees (*Bombus*) in the North American Midwest. *Biological Conservation*. (2008), doi:10.1016/j.biocon.2008.09.027
- Hatfield, R. G. and G. LeBuhn. 2007. Patch and landscape factors shape community assemblage of bumble bees, *Bombus* spp. (Hymenoptera: Apidae), in montane meadows. *Biological Conservation* 139: 150-158.
- Heinrich B. 2004. *Bumblebee Economics*. Harvard University Press, Cambridge, MA and London, England [Reissue of original 1979 edition with a new preface].
- Herrmann, F., C. Westphal, R. F. A. Moritz, and I. Steffan-Dewenter. 2007. Genetic diversity and mass resources promote colony size and forager densities of a social bee (*Bombus pascuorum*) in agricultural landscapes. *Molecular Ecology*: 1167-1178.
- Hines, H. M. and Hendrix, S. D. 2005. Bumble bee (Hymenoptera: Apidae) diversity and abundance in tallgrass prairie patches: effects of local and landscape floral resources. *Environmental Entomology* 34: 1477-1484.
- Hobbs, G. A., W. O. Nummi, and J. F. Virostek. 1961. Food-gathering behaviour of honey, bumble, and leaf-cutter bees (Hymenoptera: Apidae). *Canadian Entomologist* 93: 409-419.
- Hobbs, G.A. 1968. Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in southern Alberta. VI. Subgenus *Bombus*, *Canadian Entomologist* 100: 156-164.

- Holm, S. N. 1966. The utilization and management of bumble bees for red clover and alfalfa seed production. *Annual Review of Entomology* 11: 155-182.
- Illinois Natural History Survey Reports. 2007. Diseases of Beneficial Insects. No. 392. p.8. Available online at <http://www.inhs.uiuc.edu/inhsreports/2007/summer2007.pdf>, accessed 3/21/2008.
- Ings, T. C., N. L. Ward, and L. Chittka. 2006. Can commercially imported bumble bees out-compete their native conspecifics? *Journal of Applied Ecology* 43: 940-948.
- Inouye, D. W. 1980. The effects of proboscis and corolla tube lengths on patterns and rates of flower visitation by bumblebees. *Oecologia* 45: 197-201.
- Irwin, R. E. and A. L. Brody. 1999. Nectar-robbing bumble bees reduce the fitness of *Ipomopsis aggregata* (Polemoniaceae). *Ecology* 80: 1703-1712.
- Irwin, R. E. and J. E. Maloof. 2002. Variation in nectar robbing over time, space, and species. *Oecologia* 133: 525–533.
- Javorek, S. K., K. E. MacKenzie, and S. P. Vander Kloet. 2002. Comparative pollination effectiveness among bees on lowbush blueberry. *Annals of the Entomological Society of America* 95: 345-351.
- Jennersten, O., D. H. Morse, and P. O'Neil. 1991. Movements of male and worker bumblebees on and between flowers. *Oikos* 62: 319-324.
- Jilian, L., W. Jie, P. Wenjun, A. Jiandong, G. Zhanbao, and T. Yuemin. 2005. *Nosema bombi*, a microsporidian pathogen of the bumble bee *Bombus lucorum*. *Journal of Apicultural Science* 49: 53-57.
- Johansen, C. A. 1977. Pesticides and pollinators. *Annual Review of Entomology* 22: 177-192.
- Johansen, C. A. and D. F. Mayer. 1990. *Pollinator Protection: a Bee and Pesticide Handbook*. Wicwas Press, Cheshire, Connecticut.
- Judd, W. W. 1966. Studies of the Byron Bog in southwestern Ontario. XXIII. Insects associated with flowering leatherleaf, *Chamaedaphne calyculata* (L.) Moench. *Transactions of the American Microscopical Society* 85: 302-305.
- Kearns, C. A. and D. W. Inouye. 1997. Pollinators, flowering plants, and conservation biology. *BioScience* 47: 297-307.
- Kearns C. A., D. W. Inouye, and N. Waser. 1998. Endangered mutualisms: the conservation of plant–pollinator interactions. *Annual Review of Ecology and Systematics* 29: 83-112.

- Kevan, P. G. 1999. Pollinators as bioindicators of the state of the environment: species, activity and diversity. *Agriculture Ecosystems and Environment* 74: 373-393.
- Kevan, P. G. 1975. Forest application of the insecticide Fenitrothion and its effect on wild bee pollinators (Hymenoptera: Apoidea) of lowbush blueberries (*Vaccinium* spp.) in southern New Brunswick, Canada. *Biological Conservation* 7: 301-309.
- Kevan, P. G., S. D. Kevan, and R. M. Gadawski. 1983. Pollination of cranberries *Vaccinium macrocarpon*, on cultivated marshes in Ontario. *Proceedings of the Entomological Society of Ontario* 114: 45-53.
- Kevan, P. G. and R. C. Plowright. 1995. Impact of pesticides on forest pollination. pp. 607-618 *In* J. A. Armstrong and W. G. H. Ives (eds.) *Forest Insect Pests in Canada*. Natural Resources Canada, Canadian Forest Service, Science and Sustainable Development Directorate, Ottawa, Ontario, Canada.
- Kirby, W. 1837. The Insects. *In* Richardson, J., Swainson, W., and Kirby, W. (eds.), *Fauna Boreali-Americana*, part 4. 325 pp. Josiah Fletcher, Norwich.
- Kirilenko, A. and R. S. Hanley. 2007a. Predicting climate change impact on insect biodiversity: comparison of scenarios. pp. 453-457 *In* Proceedings of the 32nd International Symposium on Remote Sensing of Environment, San Jose, Costa Rica (June 25-29, 2007).
- Kirilenko, A. and R. S. Hanley. 2007b. Using multiple methods to predict climate change impacts on bumblebees in North America. pp. 42-47, *In* Proceedings of the International Conference on Environmental Modeling and Simulation (2007).
- Klee, J., W. Tek Tay, and R. J. Paxton. 2006. Specific and sensitive detection of *Nosema bombi* (Microsporidia: Nosematidae) in bumble bees (*Bombus* spp.; Hymenoptera: Apidae) by PCR of partial rRNA gene sequences. *Journal of Invertebrate Pathology* 91: 98-104.
- Kosior, A., W. Celary, P. Olejniczak, J. Fijat, W. Krol, W. Solarz, and P. Plonka. 2007. The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of western and central Europe. *Oryx* 41: 79-88.
- Kruess, A. and T. Tschardt. 2002a. Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biological Conservation* 106: 293-302.
- Kruess, A. and T. Tschardt. 2002b. Grazing intensity and the diversity of grasshoppers, butterflies, and trap-nesting bees and wasps. *Conservation Biology* 16: 1570-80.
- Laverty, T. and L. D. Harder. 1988. The bumble bees of eastern Canada. *Canadian Entomologist* 120: 965-987.

Leonard, M. D. 1928. A list of the insects of New York, with a list of the spiders and certain other allied groups. Cornell University Agricultural Experiment Station Memoir 101: 5-1121.

Levesque, C. M. and J. F. Burger. 1982. Insects (Diptera, Hymenoptera) associated with *Minuartia groenlandica* (Caryophyllaceae) on Mount Washington, New Hampshire, U.S.A., and their possible role as pollinators. Arctic and Alpine Research 14: 117-124.

Losey, J. E. and M. Vaughan. 2006. The economic value of ecological services provided by insects. Bioscience 56: 311-323.

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

Macfarlane, R. P., K. D. Patten, L. A. Royce, B. K. W. Wyatt, and D. F. Mayer. 1994. Management potential of sixteen North American bumble bee species. Melanderia 50: 1-12.

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

Macfarlane, R. P. and Patten, K. D. 1997. Food sources in the management of bumble bee populations around cranberry marshes. In Proceedings of the 7th International Symposium on Pollination. K. W. Richards (ed.) Acta Horticulturae: 239-244.

Macfarlane, R. P. 1998. Wisconsin: reared bumble bee and resident cranberry pollinators. Wisconsin Cranberry Crop Management Newsletter Volume XII, Number 4, June 20, 1998.

Macior, L. W. 1965. Insect adaptation and behavior in *Asclepias* pollination. Bulletin of the Torrey Botanical Club 92: 114-126.

Macior, L. W. 1968a. *Bombus* (Hymenoptera, Apidae) queen foraging in relation to vernal pollination in Wisconsin. Ecology 49: 20-25.

Macior, L. W. 1968b. Pollination adaptation in *Pedicularis groenlandica*. American Journal of Botany 55:927-932.

Macior, L. W. 1969. Pollination adaptation in *Pedicularis lanceolata*. American Journal of Botany 56: 853-859.

Macior, L. W. 1975. The pollination ecology of *Delphinium tricorne* (Ranunculaceae). American Journal of Botany 62: 1009-1016.

- Macior, L. W. 1978a. Pollination interactions in sympatric *Dicentra* species. *American Journal of Botany* 65: 57-62.
- Macior, L. W. 1978b. Pollination ecology of vernal angiosperms. *Oikos* 30: 452-460.
- Macior, L. W. 1978c. The pollination ecology and endemic adaptation of *Pedicularis furbishiae* S. Wats. *Bulletin of the Torrey Botanical Club* 105: 268-277.
- Macior, L. W. 1979. Bumble bees as pollinators of native and introduced plants. *Proceedings of the IVth International Symposium on Pollination, Maryland Agricultural Experiment Station Special Miscellaneous Publication 1*: 441-446.
- MacKenzie, K. E. and A. L. Averill. 1995. Bee (Hymenoptera: Apoidea) diversity and abundance on cranberry (*Vaccinium macrocarpon* Aiton) in southeastern Massachusetts. *Annals of the Entomological Society of America* 88: 334-341.
- Malone, L. A. and M. Pham-Delègue. 2001. Effects of transgene products on honey bees (*Apis mellifera*) and bumblebees (*Bombus* sp.). *Apidologie* 32: 287-304.
- Maloof, J. E. 2001. The effects of a bumble bee nectar robber on plant reproductive success and pollinator behavior. *American Journal of Botany* 88: 1960-1965.
- Matsumura, C., M. Nakajima, J. Yokoyama, and I. Washitani. 2004. High reproductive ability of an alien bumblebee invader, *Bombus terrestris* L., in the Hidaka region of southern Hokkaido, Japan. *Japanese Journal of Conservation Ecology* 9: 93-101.
- Mayer, D. F., K. D. Patten, and R. P. Macfarlane. 1994. Pear pollination with managed bumble bee (Hymenoptera: Apidae) colonies. *Melandria* 50: 20-23.
- Mayer, D. F. and J. D. Lunden. 1997. A comparison of commercially managed bumblebees and honey bees (Hymenoptera: Apidae) for pollination of pears. *In Proc. 7th International Symposium on Pollination*. K. W. Richards (ed.) *Acta Horticulturae* 437: 283-287.
- Mayer, D. F. and J. D. Lunden. 2001. Honey bee management and wild bees for pollination of hybrid onion seed. *In Proceeding of the 8th International Symposium on Pollination* P. Benedek and K. W. Richards (eds.) *Acta Horticulturae* 561: 275-278.
- McFrederick, Q. S. and G. LeBuhn. 2006. Are urban parks refuges for bumble bees *Bombus* spp. (Hymenoptera : Apidae)? *Biological Conservation* 129: 372-382.
- McFrederick, Q. S., J. C. Kathilankal, J. D. Fuentes. 2008. Air pollution modifies floral scent trails. *Atmospheric Environment* 42: 2336-2348.
- Medler, J. T. 1962. Morphometric studies on bumble bees. *Annals of the Entomological Society of America* 55: 212-218.

- Medler, J. T. and D. W. Carney. 1963. Bumblebees of Wisconsin (Hymenoptera: Apidae). Research Bulletin, University of Wisconsin, Agricultural Experiment Station 240: 47 pp.
- Meisels, S. and H. Chiasson. 1997. Effectiveness of *Bombus impatiens* Cr. As pollinators of greenhouse sweet peppers (*Capsicum annuum* L.). In Proc. 7th International Symposium on Pollination. K. W. Richards (ed.) Acta Horticulturae 437: 425-429.
- Memmott, J., N. M. Waser, and M. V. Price. 2004. Tolerance of pollination networks to species extinctions. Proceedings of the Royal Society B 271: 2605-2611.
- Milliron, H. E. 1971. A monograph of the western hemisphere bumblebees (Hymenoptera: Apidae; Bombinae). I. The genera *Bombus* and *Megabombus* subgenus *Bombias*. Memoirs of the Entomological Society of Canada 82: 1-80.
- Mitchell, T. B. 1962. Bees of the Eastern United States. Vol. II. North Carolina Agricultural Experiment Station Technical Bulletin 152: 1-557.
- Mommaerts, V., G. Sterk, and G. Smagghe. 2006. Hazards and uptake of chitin synthesis inhibitors in bumblebees *Bombus terrestris*. Pest Management Science 62: 752-758.
- Morandin, L. A., M. L. Winston, M. T. Franklin, and V. A. Abbott . 2005. Lethal and sublethal effects of spinosad on bumble bees (*Bombus impatiens* Cresson). Pest Management Science 61: 619-626.
- Morris, M. 1967. Differences between invertebrate faunas of grazed and ungrazed chalk grassland. I. Responses of some phytophagous insects to cessation of grazing. Journal of Applied Ecology 4: 459-474.
- National Research Council. 2007. Status of Pollinators in North America. The National Academies Press, Washington, DC.
- Ne'eman, G., R. Ne'eman, and A. M. Ellison. 2006. Limits to reproductive success of *Sarracenia purpurea* (Sarraceniaceae). American Journal of Botany 93: 1660-1666.
- Niwa, S., H. Iwano, S. Asada, M. Matsuura, and K. Goka. 2004. A microsporidian pathogen isolated from a colony of the European bumblebee, *Bombus terrestris*, and infectivity on Japanese bumblebee. Japanese Journal of Applied Entomology and Zoology 48: 60-64 (in Japanese with English abstract).
- Öckinger, E. and H. G. Smith. 2007. Semi-natural grasslands as population sources for pollinating insects in agricultural landscapes. Journal of Applied Ecology 44: 50-59.

O'Mahoney, E. M., W. T. Tay, and R. J. Paxton. 2007. Multiple rRNA variants in a single spore of the microsporidian *Nosema bombi*. *Journal of Eukaryotic Microbiology* 54: 103-109.

Otterstatter, M. C., R. J. Gegear, S. R. Colla, and J. D. Thomson. 2005. Effects of parasitic mites and protozoa on the flower constancy and foraging rate of bumble bees. *Behavioral Ecology and Sociobiology* 58: 383-389.

Otterstatter, M. C. and T. L. Whidden. 2004. Patterns of parasitism by tracheal mites (*Locustacarus buchneri*) in natural bumble bee populations. *Apidologie* 35: 351-357.

Otterstatter, M. C., and J. D. Thomson. 2008. Does pathogen spillover from commercially reared bumble bees threaten wild pollinators? *PLoS ONE* 3: e2771. doi:10.1371/journal.pone.0002771
<http://www.plosone.org/doi/pone.0002771>

Otti, O. and P. Schmid-Hempel. 2007. *Nosema bombi*: A pollinator parasite with detrimental fitness effects. *Journal of Invertebrate Pathology* 96: 118–124.

Otti, O. and P. Schmid-Hempel. 2008. A field experiment on the effect of *Nosema bombi* in colonies of the bumblebee *Bombus terrestris*. *Ecological Entomology* 33: 577–582.

Packer, L. and R. Owen. 2001. Population genetic aspects of pollinator decline. *Conservation Ecology* 5: Article 4.

Patten, K. D., C. H. Shanks, and D. F. Mayer. 1993. Evaluation of herbaceous plants for attractiveness to bumble bees for use near cranberry farms. *Journal of Apicultural Research* 32: 73-79.

Peat, J., J. Tucker, and D. Goulson. 2005. Does intraspecific size variation in bumblebees allow colonies to efficiently exploit different flowers? *Ecological Entomology* 30: 176-181.

Pellmyr, O. 1985. Pollination ecology of *Cimicifuga arizonica* (Ranunculaceae). *Botanical Gazette* 146: 404-412.

Pidduck, W. L. and R. J. McNeil. 2001. The effectiveness of the western bumblebee (*Bombus occidentalis*) in pollinating 'Hass' avocado trees. *Hortscience* 36: 496-497.

Plath, O. E. 1927. Notes on the nesting habits of some of the less common New England bumblebees. *Psyche* 34: 122-128.

Plath, O. E. 1934. *Bumblebees and Their Ways*. The MacMillan Company, New York, NY.

- Plowright, R. C., B. A. Pendrel, and I. A. McLaren. 1978. The impact of aerial fenitrothion spraying upon the population biology of bumble bees (*Bombus* Latr: Hym.) in south-western New Brunswick. *Canadian Entomologist* 110: 1145-1156.
- Plowright, R. C., J. D. Thomson, and G. R. Thaler. 1980. Pollen removal in *Cypripedium acaule* (Orchidaceae) in relation to aerial fenitrothion spraying in New Brunswick. *Canadian Entomologist* 112: 765-769.
- Plowright, R. C. and Galen, C. 1985. Landmarks or obstacles: the effects of spatial heterogeneity on bumble bees foraging behavior. *Oikos* 44: 459-464.
- Plowright, C. M. S. and Plowright, R. C. 1997. The advantage of short tongues in bumble bees (*Bombus*) : analyses of species distributions according to flower corolla depth, and of working speeds on white clover. *Canadian Entomologist* 129: 51-59.
- Plowright, C. M. S. and Plowright, R. C. 1998. Floral use by two sympatric bumble bee species (*Bombus terricola* and *Bombus ternarius*): efficiency considerations. *Canadian Entomologist* 130: 595-60.
- Poole, R. W. 1996. *Nomina Insecta Nearctica*, a checklist of the insects of North America. Volume 2: Hymenoptera, Mecoptera, Megaloptera, Neuroptera, Raphidioptera, Trichoptera. Entomological Information Services, Rockville, MD.
- Primack, D., C. Imbres, R. B. Primack, A. J. Miller-Rushing, and P. Del Tredici. 2004. Herbarium specimens demonstrate earlier flowering times in response to warming in Boston. *American Journal of Botany* 91: 1260-1264.
- Pyke, G. H. 1982. Local geographic distributions of bumblebees near Crested Butte, Colorado: competition and community structure. *Ecology* 63: 555-573.
- Rao, S. and W. P. Stephen. 2007. *Bombus* (*Bombus*) *occidentalis* (Hymenoptera: Apiformes): in decline or recovery? *The Pan-Pacific Entomologist* 83: 360-362.
- Rasmont, P., A. Pauly, M. Terzo, S. Patiny, D. Michez, S. Iserbyl, Y. Barbier, and E. Haubruge. 2006. The survey of wild bees (Hymenoptera, Apoidea) in Belgium and France. p.18 *In* Status of the World's Pollinators. Food and Agriculture Organization of the United Nations, Rome.
- Reed, C. C. 1995. Species richness of insects on prairie flowers in southeastern Minnesota. *Proceedings of the 14th North American Prairie Conference*: 103-115.
- Richards, K. W. and T. W. Myers. 1997. Commercially managed colonies of bumblebees for pollination of cicer milkvetch. *In* Proceedings of the 7th International Symposium on Pollination. K.W. Richards (ed.). *Acta Horticulturae* 437: 293-297.
- Roy, D. B. and T. H. Sparks. 2000. Phenology of British butterflies and climate change.

Global Change Biology 6: 407-416.

Ronny Larson, J. I. 2007. Cytological variation and pathogenicity of the bumble bee parasite *Nosema bombi* (Microspora, Nosematidae). *Journal of Invertebrate Pathology* 94: 1-11.

Ruiz-Gonzalez, M. X. and M. J. F. Brown. 2006. Honey bee and bumblebee trypanosomatids: specificity and potential for transmission. *Ecological Entomology* 31: 616-622.

Rutrecht, S. T., J. Klee, and M. J. F. Brown. 2007. Horizontal transmission success of *Nosema bombi* to its adult bumble bee hosts: effects of dosage, spore source and host age. *Parasitology* 134: 1719-1726.

Scholl, A., E. Obrecht, and R. E. Owen. 1990. The genetic relationship between *Bombus moderatus* Cresson and the *Bombus lucorum* auct. species complex (Hymenoptera: Apidae). *Canadian Journal of Zoology* 68: 2264-2268.

Scholl, A., R. W. Thorp, and E. Obrecht. 1992. The genetic relationship between *Bombus franklini* (Frison) and other taxa of the subgenus *Bombus* s. str. (Hymenoptera: Apidae). *Pan-Pacific Entomologist* 68: 46-51.

Schultz, C. B. 1998. Ecology and Conservation of the Fender's Blue Butterfly. PhD. Dissertation, University of Washington, Seattle, WA.

Shaw, F. R., J. S. Bailey, and A. I. Bourne. 1939. The comparative value of honeybees in the pollination of cultivated blueberries. *Journal of Economic Entomology* 32: 872-874.

Shepherd, M., S. L. Buchmann, M. Vaughan, and S. H. Black. 2003. Pollinator Conservation Handbook. The Xerces Society, Portland, Oregon.

Sjodin, N. E. 2007. Pollinator behavioural responses to grazing intensity. *Biodiversity Conservation* 16: 2103-2121.

Smallidge, P. J. and D. J. Leopold. 1997. Vegetation management for the maintenance and conservation of butterfly habitats in temperate human-dominated habitats. *Landscape and Urban Planning* 38: 259-280.

Speight, D. L. 1967. The bumblebees (Hymenoptera, Apidae, Bombinae) of east Tennessee. Master's Thesis, University of Tennessee, Knoxville, TN.

Spiewok, S. and P. Neumann. 2006. Infestation of commercial bumblebee (*Bombus impatiens*) field colonies by small hive beetles (*Aethina tumida*). *Ecological Entomology* 31: 623-628.

Stephen, W. P. 1955. Alfalfa pollination in Manitoba. *Journal of Economic Entomology*

48: 543-548.

Stephen, W. P. 1957. Bumble Bees of Western America. Oregon State College, Agricultural Experiment Station, Technical Bulletin 40.

Stevens, O. A. 1948. Native bees. Bumblebees. Bimonthly Bulletin, North Dakota Agricultural Experiment Station 11: 49-54.

Stiles, E. W. 1977. Foraging behavior of bumblebees (*Bombus impatiens*, *Bombus vagans*, *Bombus affinis*) on false foxglove (*Aureolaria pedicularia*). Journal of the New York Entomological Society 85: 249-252.

Stubbs, C. S. and F. A. Drummond. 1997. Blueberry and cranberry (*Vaccinium* spp.) pollination: a comparison of managed and native bee foraging behavior. In Proceedings of the 7th International Symposium on Pollination. K. W. Richards (ed.) Acta Horticulturae 437: 341-344.

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

Sugden, E. A., R. W. Thorp, and S. L. Buchmann. 1996. Honey bee-native bee competition: focal point for environmental change and agricultural response in Australia. Bee World 77: 26-44.

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

Thomson, D. M. 2006. Detecting the effects of introduced species: a case study of competition between *Apis* and *Bombus*. Oikos 114: 407-418.

Thomson, J. D. 1986. Pollen transport and deposition by bumble bees in *Erythronium*: influences of floral nectar and bee grooming. Journal of Ecology 74: 329-341.

Thompson, H. M. and L. V. Hunt. 1999. Extrapolating from honeybees to bumblebees in pesticide risk assessment. Ecotoxicology 8: 147-166.

Thompson, H. M. 2001. Assessing the exposure and toxicity of pesticides to bumblebees (*Bombus* sp.). Apidologie 32: 305-321.

Thorp, R. W., D. S. Horning and L. L. Dunning. 1983. Bumble bees and cuckoo bumble bees of California (Hymenoptera: Apidae). Bulletin of the California Insect Survey 23: viii.

Thorp, R. W. 2003. Bumble Bees (Hymenoptera: Apidae): Commercial use and environmental concerns. pp. 21-40. In K. Strickler and J. H. Cane (eds.). For nonnative crops, whence pollinators of the future? Thomas Say Publications in Entomology:

Proceedings. Entomological Society of America, Lanham, MD.

Thorp, R. W. 2005. *Bombus franklini* Frison, 1921 Franklin's Bumble Bee (Hymenoptera: Apidae: Apinae: Bombini). In Shepherd, M. D., D. M. Vaughan, and S. H. Black (eds.) Red List of Pollinator Insects of North America. CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation.
www.xerces.org/Pollinator_Red_List/Bees/Bombus_franklini.pdf

Thorp, R. W. and Shepherd, M. D. 2005. Subgenus *Bombus*. Latreille, 1802 (Apidae: Apinae: Bombini). In Shepherd, M. D., D. M. Vaughan, and S. H. Black (eds.) Red List of Pollinator Insects of North America. CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation.
www.xerces.org/Pollinator_Red_List/Bees/Bombus_Bombus.pdf

Thorp, R. W. 2008. Franklin's Bumble Bee, *Bombus (Bombus) franklini* (Frison) (Hymenoptera: Apidae). Report on 2006-2007 Seasons (Submitted 10 March 2008).

Tommasi, D., A. Miro, H. A. Higo, and M. L. Winston. 2004. Bee diversity and abundance in an urban setting. *The Canadian Entomologist* 136: 851-869.

Vazquez, D. P. and D. Simberloff. 2003. Changes in interaction biodiversity induced by an introduced ungulate. *Ecology Letters* 6: 1077-1083.

Velthuis, H. H. W. and A. van Doorn. 2006. A century in advances in bumblebee domestication and the economic and environmental aspects of its commercialization for pollination. *Apidologie* 37: 421-451.

Warren, M. S. 1993. A review of butterfly conservation in central southern Britain: II. site management and habitat selection of key species. *Biological Conservation* 64: 37-49.

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

Whittington, R., M. L. Winston, C. Tucker, and A. L. Parachnowitsch. 2004. Plant-species identity of pollen collected by bumblebees placed in greenhouses for tomato pollination. *Canadian Journal of Plant Science* 84: 599-602.

Williams, P. H. 1986. Environmental change and the distribution of British bumble bees (*Bombus* Latr.). *Bee World* 67: 50-61.

Williams, P. H. 1998. An annotated checklist of bumble bees with an analysis of patterns of description (Hymenoptera: Apidae, Bombini). *Bulletin of the Natural History Museum, London (Ent.)* 67: 79-152. updated at:
www.nhm.ac.uk/research-curation/projects/bombus/

Williams, P. H., M. B. Araujo, and P. Rasmont. 2007. Can vulnerability among British bumblebee (*Bombus*) species be explained by niche position and breadth? *Biological Conservation* 138: 493–505.

Williams, P. H., S. A. Cameron, H. M. Hines, B. Cederberg, and P. Rasmont. 2008. A simplified subgeneric classification of the bumblebees (genus *Bombus*). *Apidologie* 39: 46-74.

Winston, M. L. and L. H. Graf. 1982. Native bee pollinators of berry crops in the Fraser Valley of British Columbia. *Journal of the Entomological Society of British Columbia* 79: 14-20.

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

IX. ACKNOWLEDGEMENTS AND PERSONAL COMMUNICATION

We appreciate the following individuals who carefully reviewed this document: Sheila Colla, James Strange, Paul Williams, Gabriela Chavarria, Sylvia Fallon and Andrew Wetzler. Liz Day was especially helpful in providing information on the current and historic distribution of *Bombus affinis* and *Bombus terricola*.

Personal communication was cited in this report with these individuals:

Dr. John Ascher, American Museum of Natural History, Aug. 2008

Rick Bettge, Aug. 2008

Matthew Bowser, Kenai National Wildlife Refuge, Jan. 2008

Dr. Ralph Cartar, University of Calgary, Apr. 2008

Dr. Sandy DeBano, Oregon State University, Hermiston Field Station, Apr. 2008

Jodi DeLong, freelance writer, Jan. 2008

Sam Droege, USGS Patuxent Wildlife Research Center, Feb. 2008

Elaine Evans, Xerces Society (cited: personal observation), August 2007 and July 2008

R. Gegear, May 2008

Jennifer Gixti and Colin Favret, University of Illinois, Nov. 2007

Dr. Bernd Heinrich, Professor Emeritus, University of Vermont, Sept. 2007; Aug. 2008

Dr. Steve Hendrix (Professor) and Chris Gienapp, University of Iowa, Sept. 2007

Dr. David W. Inouye, Professor, University of Maryland, Sept. 2007; July 2008

Robert Jacobson, Sept. 2007

Johanna James-Heinz, Sept. 2008

Robert Jean and Peter E. Scott, Indiana State University, Sept. 2007

Sarina Jepsen, The Xerces Society (cited: personal observation), Mar. 2008

Chiho Kimoto, Oregon State University, Hermiston Field Station, Apr. 2008

Dr. Kenna MacKenzie, Agriculture and Agri-Food Canada, July 2008

Adriean J. Mayor, Great Smoky Mountains National Park, Sept. 2007

Christina North, graduate student, University of Illinois, Oct. 2007

Dr. Michael Otterstatter, University of Toronto, Mar. 2008

Dr. Catherine Reed, July 2008

Dale Reimer, retired, Mar. 2008
Leif Richardson, Vermont Nongame and Natural Heritage Program, Aug. 2008
Dr. Tai Roulston, Research Associate Professor, University of Virginia, Sept. 2007
Sue Sheehan, Fermilab, Batavia, IL, Mar. 2008
Dr. Lee Solter, Illinois Natural History Survey, Mar. 2008
Dr. James Strange, USDA-ARS Logan-Bee Lab, Sept. 2007; June 2008
Dr. Larry Stevens, Museum of Northern Arizona, Feb. 2008
Dr. Robbin Thorp, Professor Emeritus, University of California, Davis, Sept. 2008
Michael Veit, Lawrence Academy, Massachusetts, June 2008
Wayne Wehling and Colin Stewart, USDA-APHIS, Maryland, April 2008
Dr. Paul Williams, The Natural History Museum, London, UK, July 2008

The following individuals contributed information to our understanding of the status of North American bumble bees in the subgenus *Bombus sensu stricto*:

Dr. Kevin Alexander, Western State College of Colorado
Dr. Sydney Cameron, University of Illinois
Dr. Elizabeth Elle, Simon Fraser University
Dr. Doug Golick, University of Nebraska
Dr. John Neff, Central Texas Melittological Institute
Barbara Peterson, Canadian Food Inspection Agency
Mike Quinn, Texas Parks and Wildlife
Dr. Pete Schroeder, Southern Oregon University
Dr. W.P. Stephen, Professor Emeritus, Oregon State University

X. APPENDIX I

Note that the following lists of *B. affinis*, *B. terricola* and *B. occidentalis* specimens are not a comprehensive list of all of the specimens in museums. Appendix I A, B, and C represent a list of collected specimens from a few major museums. Data from the American Museum of Natural History were provided by John Ascher and Jerry Rozen. The data from Kansas University were put together by Charles Michener, Michael Engel and Rob Brooks. The data from Illinois were compiled by Doug Yanega and Ron McGinley. Data on specimens from Iowa State University and the University of Minnesota were collected by Elaine Evans. Data on specimens at the Illinois Natural History Survey were obtained through their on-line database. Data on specimens at the Great Smoky Mountain National Park were provided by Adrieen Mayor. Data on specimens in Michael Veit's collection were provided by Michael Veit. Data from the University of Idaho Barr Collection and Washington State University James Collection were provided by James Strange. Data from Southern Oregon State University were provided by Pete Schroeder. Data for specimens at the U.S. National Pollinating Insects Collection was provided by Larry Stevens.

Museum specimens are summarized as follows:

If there is more than one record from the same date and location that number is noted first, followed by: location, date of collection, collected by, museum holding specimen, male or gyne (if noted). Abbreviations for collectors are as follows: Mich is C Michener, Rindge is F Rindge, P Rindge & B Rindge, Davis is EJ Davis, Nott is Nottingham.

Abbreviations for museums are as follows: AMNH is the American Museum of Natural History, GSMNP is Great Smokey Mountain National Park, INHS is Illinois Natural History Survey, KU is Kansas University Snow Entomology Collection, U of MN is the University of Minnesota Insect Collection, IS is Iowa State University Entomology Collection, UIBC is University of Idaho Barr Collection, SOU is Southern Oregon State University, USDA/USU is the U.S. National Pollinating Insects Collection and WSU is Washington State University James Collection.

A. *Bombus affinis* museum records

CANADA

Ontario: Chatham, 23-Aug-1913, F.W.L. Sladen, INHS, male; Portage Co., Stewart Lake, 1-Aug-1936, D.W. Jenkins, INHS; Portage Co., Stewart Lake, 1-Aug-1936, D.W. Jenkins, INHS

Quebec: Parc Gatineau, 1-Jul-1965, Corbett, Miller, KU

UNITED STATES OF AMERICA

Colorado: Gratiot, 12-Sep-1937, Dreisbach, T.H. Frison, INHS, male

Connecticut: Hartford, 11-Aug-1895, unknown, T.H. Frison, INHS, male; Putnam, 23-Aug-1933, A.B. Klots, T.H. Frison, INHS

Illinois: 5: Volo, 26-Aug-1925, T.H. Frison, T.H. Frison, INHS; Palos, 26-Jun-1930, J. Pearson, T.H. Frison, INHS; Waukegan, 23-Aug-1930, C. Seevers, T.H. Frison, INHS; Urbana, 30-Jun-1966, E. R. Jaycox, J. Grixti, INHS; Urbana, 29-Aug-1966, E. R. Jaycox, J. Grixti, INHS; Trelease Woods, Urbana, 15-May-1970, J. Grixti, INHS; Volo Bog Nature Preserve, 2 mi NW Volo, 17-Jul-1978, E.A. Lisowski, J. Grixti, INHS; 4 mi E. Shapville, 8-Aug-1980, E. Miliczky, J. Grixti, INHS; Winthrop Harbor, Spring Bluff Forest Preserve, 19-May-1999, Kuysz & Lees, Brooks, KU; 3: Libertyville, 6 mi SE, Elm Road, 29-Jul-1999, Kuysz & Lees, Brooks, KU; Libertyville, 6 mi SE, Grainger Woods, 1-Aug-1999, Kuysz & Lees, unknown, KU; Libertyville, 6 mi SE, Elm Road, 10-Aug-1999, Kuysz & Lees, unknown, KU; Libertyville, 6 mi SE, Elm Road, 29-Jul-1999, Kuysz & Lees, unknown, KU

Iowa: Ames, 23-Apr-1956, O. R. Wade, IS, gyne; Ames, 26-May-1956, R. Boenke, IS, gyne; Ledges St Pk, 30-Sep-1956, M. Johnson, IS; Ledges St Pk, 20-Sep-1971, D.C. Dennis, IS

Massachusetts: Amherst, 16-Aug-1904, H.J.F., T.H. Frison, INHS; Sherborn, 11-Jun-1913, E.J. Smith, T.H. Frison, INHS; Sherborn, 24-Jul-1913, E.J. Smith, T.H. Frison, INHS; Sherborn, 26-Jul-1913, C.A. Frost, T.H. Frison, INHS; Sherborn, 15-Aug-1913, E.J. Smith, T.H. Frison, INHS, male; Sherborn, 8-Sep-1913, E.J. Smith, T.H. Frison, INHS, male; Sherborn, 9-Sep-1913, E.J. Smith, T.H. Frison, INHS, male; Sherborn, 9-Sep-1913, E.J. Smith, T.H. Frison, INHS; Forest Hills, 12-Sep-1913, F.X. Williams, T.H. Frison, INHS; Sherborn, 28-May-1914, E.J. Smith, T.H. Frison, INHS; Framingham, 2-Aug-1914, C.A. Frost, T.H. Frison, INHS; Sherborn, 22-Aug-1914, C.A. Frost, T.H. Frison, INHS, male; Sherborn, 22-Aug-1914, C.A. Frost, T.H. Frison, INHS; Sherborn, 30-Aug-1914, C.A. Frost, T.H. Frison, INHS; Framingham, 27-Sep-1914, C.A. Frost, T.H. Frison, INHS, male; Framingham, 27-Sep-1914, C.A. Frost, T.H. Frison, INHS, Female; Sherborn, 7-May-1915, E.J. Smith, T.H. Frison, INHS; Framingham, 14-Aug-

1915, unknown, T.H. Frison, INHS, male; Framingham, 14-Aug-1915, C.A. Frost, T.H. Frison, INHS; Framingham, 28-Aug-1915, C.A. Frost, T.H. Frison, INHS; Framingham, 5-Sep-1915, C.A. Frost, T.H. Frison, INHS; Framingham, 5-Sep-1915, C.A. Frost, T.H. Frison, INHS; Framingham, 3-Sep-1916, C.A. Frost, T.H. Frison, INHS; 2: Framingham, 16-Sep-1916, C.A. Frost, T.H. Frison, INHS, male; Framingham, 16-Sep-1916, unknown, T.H. Frison, INHS; Framingham, 16-Sep-1916, C.A. Frost, T.H. Frison, INHS; 3: Sherborn, 16-Sep-1917, C.A. Frost, T.H. Frison, INHS, male; 3: Sherborn, 16-Sep-1917, C.A. Frost, T.H. Frison, INHS

Michigan: Onekama, 12-Jul-1914, A.D. MacG., T.H. Frison, INHS, Female; Onekama, 12-Jul-1915, A.D. McG, T.H. Frison, INHS, Female; Ludington, 22-Aug-1915, T.H. Frison, T.H. Frison, INHS; Crystal Lake, 26-Aug-1919, E.P. Butler, T.H. Frison, INHS; Portage Lake, 6-Aug-1924, F.M. Gaige, T.H. Frison, INHS, male; Ann Arbor, 21-Sep-1924, F.M. Gaige, T.H. Frison, INHS, male; Portage Lake, 12-Oct-1924, F.M. Gaige, T.H. Frison, INHS, male; Midland County, 25-Aug-1937, R.R. Dreisbach, T.H. Frison, INHS; Reed Road, 18-Aug-1982, G.P. Waldbauer, W.E. LaBerge, INHS

Minnesota: near Garrison, Mille Lacs Lake, 2-Oct-1938, R.W. Dawson, H.E. Milliron, INHS, male; 5: Long Lake Regional Park, 11-Jul-1994, C. Reed, E. Evans, U of MN; 28: Long Lake Regional Park, 14-Jul-1994, C. Reed, E. Evans, U of MN; 26: Long Lake Regional Park, 19-Jul-1994, C. Reed, E. Evans, U of MN; 4: Long Lake Regional Park, 10-Jul-1995, C. Reed, E. Evans, U of MN; 3: Long Lake Regional Park, 13-Jul-1995, C. Reed, E. Evans, U of MN; Long Lake Regional Park, 17-Jul-1995, C. Reed, E. Evans, U of MN; 5: Long Lake Regional Park, 20-Jul-1995, C. Reed, E. Evans, U of MN; 8: Long Lake Regional Park, 24-Jul-1995, C. Reed, E. Evans, U of MN; 9: Long Lake Regional Park, 31-Jul-1995, C. Reed, E. Evans, U of MN; 2: Long Lake Regional Park, 2-Aug-1995, C. Reed, E. Evans, U of MN; 3: Long Lake Regional Park, 7-Aug-1995, C. Reed, E. Evans, U of MN; 4: Long Lake Regional Park, 9-Aug-1995, C. Reed, E. Evans, U of MN

New Hampshire: Center Harbor, Jul-1938, Lawson, unknown, KU

New Jersey: Riverton, 18-Aug-1901, unknown, T.H. Frison, INHS, male

New York: 3: Ithaca, 04-Aug-1885, Coville, Frison, KU; Ithaca, 1-Jul-1904, unknown, T.H. Frison, INHS; Ithaca, 6-Aug-1904, unknown, T.H. Frison, INHS, male; Newport, 18-Aug-1904, N.Y.S., T.H. Frison, INHS, male; 2: Mt. Sinai Harbor, Long Island, 3-Sep-1922, G.P. Engelhardt, T.H. Frison, INHS; Ithaca, 10-Aug-1928, A.R. Park, T.H. Frison, INHS; Rochester, 16-Apr-1932, unknown, T.H. Frison, INHS; Fishers, 16-Jul-1933, unknown, T.H. Frison, INHS, male; Fishers, 6-Aug-1933, T.H. Frison, INHS; 2: Rochester, 12-Aug-1933, unknown, T.H. Frison, INHS, male; Fishers, 10-Sep-1933, unknown, T.H. Frison, INHS, male

North Carolina: Grandfather Mountain, 11-Sep-1908, Z.P. Metcalf, T.H. Frison, INHS, male; Andrews bald, 22-Sep-1939, A. Stupka, R.R. Dreisbach, GSMNP; Forney Ridge trail below Clingmans Dome parking lot, 30-Jul-1989, K. Langdon, W. Macior, GSMNP

North Carolina / Tennessee: Mt Buckley, 11-Aug-1959, K.D. Snyder, D. De Foe, GSMNP

Ohio: Put-in-Bay, Kelleys Island, 10-Sep-1933, T.H. Frison, INHS, male

Pennsylvania: Mt Holly Springs, 1-Sep-1918, R.M. Fouts, T.H. Frison, INHS, male

South Dakota: Waubay, 13-Sep-1929, H.C. Severin, T.H. Frison, INHS, male

Tennessee: Sugarlands, 11-Apr-1945, A. Stupka, R. R. Dreisbach, GSMNP; Park Headquarters, 5-Apr-1979, R.G. Cardwell, D. De Foe, GSMNP; Park Headquarters, 31-Aug-1980, D. De Foe, D. De Foe, GSMNP; Park Headquarters, 17-Mar-1982, D. De Foe, D. De Foe, GSMNP; Park Headquarters, 28-Mar-1982, D. De Foe, D. De Foe, GSMNP; Mt Leconte, 31-Aug-1939, A. Stupka, D. De Foe, GSMNP; Fighting Creek Gap, 26-Aug-1941, A.J. Sharp, D. De Foe, GSMNP; Park Headquarters, 26-Aug-1941, A.J. Sharp, D. De Foe, GSMNP; Fighting Creek Gap, 26-Aug-1941, A.J. Sharp, D. De Foe, GSMNP; 3: Fighting Creek Gap, 8-Sep-1946, A.J. Sharp, D. De Foe, GSMNP; 2: Park Headquarters, 15-Aug-1947, Bullock & Dreisbach, D. De Foe, GSMNP; Park Headquarters, 27-Aug-1980, D. De Foe, D. De Foe, GSMNP; Park Headquarters, 31-Aug-1980, D. De Foe, D. De Foe, GSMNP; 2: Park Headquarters, 8-Sep-1980, D. De Foe, D. De Foe, GSMNP; Cades Cove Forge Creek Road, 28-Jul-1997, H. Hamilton, D. De Foe, GSMNP; Copeland Creek, 16-Sep-2000, A. Mayor & D. Paulsen, A. Mayor, GSMNP; 2: Gregory Bald, 18-Jun-2000, A. Mayor, A. Mayor, GSMNP

Virginia: White Rocks Campground; 3 mi SE Kire, 20-Aug-1971, Byers, Miller, KU; Montgomery, Poverty Creek, 13-Aug-1979, Byers, Miller, KU

West Virginia: Braxton, Frametown, 5 km W, 14-Jul-1996, Alexander, unknown, KU

B. *Bombus terricola* museum records

CANADA

Alberta: (Records for Alberta may be either *B. occidentalis* or *B. terricola*) 4: unknown loc., 14-May-1890, Bean, unknown, AMNH, gyne; unknown loc., 10-Aug-1890, Bean, unknown, AMNH, male; unknown loc., 12-Jun-1893, Bean, unknown, AMNH, gyne; unknown loc., 16-May-1893, Bean, unknown, AMNH, gyne; unknown loc., 17-May-1893, Bean, unknown, AMNH, gyne; 9: Prairie Bluff Mt, 29-Jul-1971, Mich, unknown, KU; 6: High River, 35 mi. W, 5-Aug-1975, Mich, unknown, KU; Picture Butte, 3 mi SE, 14-Jun-1982, Mich, unknown, KU

Newfoundland: 7: Gros Morne N'tl Pk Visitor Center, 8-Aug-1999, Brzoska, Ascher, KU; Gros Morne N'tl Pk Rocky Harbour, 8-Aug-1999, Brzoska, Michener, KU; 34: Gros Morne N'tl Pk Shallow Bay C.G., 8-Aug-1999, Brzoska, Ascher, KU

Saskatchewan: (Record for Saskatchewan may be either *B. occidentalis* or *B. terricola*): Swift Current, 1-Aug-1971, Mich, unknown, KU; 6: Athabasca S.D.P.P., Thomas Bay, 17-Jul-2000, Brzoska, Brooks, KU

UNITED STATES OF AMERICA

New Hampshire: Washington, 28-Jul-2002, M. Veit, M. Veit, male, M. Veit; Mt Washinton N'tl Forest, 1-Aug-2002, M. Veit, M. Veit, male, M. Veit; Mt Washinton Regional Airport, Whitefield, 26-Jul-2006, M. Veit, M. Veit, M. Veit; Cherry Ponds N'tl Wildlife Refuge, Jefferson, 25-Jul-2007, M. Veit, M. Veit, M. Veit

Montana (Records for Montana may be either *B. occidentalis* or *B. terricola*): 3: Beaver Creek, 1-Aug-1913, Hunter, unknown, KU; Avalanche Creek, Glacier N'tl Pk, 12-Jul-1920, Nast, unknown, KU; Haugan, 9-Aug-1931, Anderson, unknown, KU; 3: Haugan, 9-Aug-1931, Beamer, unknown, KU; Haugan, 9-Aug-1931, Nott, unknown, KU; Haugan, 9-Aug-1931, Peters, unknown, KU; 2: Missoula, 11-Aug-1931, Nott, unknown, KU; Missoula, 11-Aug-1931, Sanderson, unknown, KU; 3: Bozeman, 13-Aug-1931,

Beamer, unknown, KU; 2: Bozeman, 13-Aug-1931, Nott, unknown, KU; Hamilton, 17-Jul-1949, Beamer, unknown, KU; Como Lake, 17-Jul-1949, Beamer, unknown, KU; Como Lake, 17-Jul-1949, White, unknown, KU; 2: Skalkaho Pass, Hamilton, 19-Jul-1949, Beamer, unknown, KU; Skalkaho Pass, Hamilton, 1-Aug-1949, White, unknown, KU; Skalkaho Pass, 2: near Hamilton, 1-Aug-1949, White, unknown, KU; Lost Horse Canyon, Hamilton, 2-Aug-1949, Beamer, unknown, KU; Lost Horse Canyon, Hamilton, 2-Aug-1949, White, unknown, KU; Hamilton, 9-Jun-1956, Miura, unknown, KU; 1.7 mi E Below Summit Bannock Pass, 20-May-1956, unknown, Strange, U of ID, gyne; Pintlar Meadow, 22-Jul-1957, D. Cox, Strange, WSU, gyne; Ekalaka, 7 mi. S; Custer N'tl Forest, 9-Aug-1967, Hepburn, unknown, KU; Florence; near, 10-Jun-1980, Yanega, unknown, KU; Monarch; 8 mi N, 19-Jun-1982, Mich, unknown, KU; McGregor Lake, Kalispell, 57 km W from, 3-Jul-1982, Brooks, unknown, KU

North Carolina: Forney Ridge trail below Clingmans Dome Parking area, 30-Jul-1989, K Langdon, W. Macior, GSMNP

North Carolina/ Tennessee: Silers Bald trail, 23-Jul-1936, Wollerman, D. De Foe, GSMNP; Silers Bald trail, 23-Jul-1936, R.F. Kujowich, R.R. Dreisbach; Spence Field, 13-Aug-1947, Bullock & Dreisbach, H.E. Milliron, GSMNP; Mt Buckley, 2-Aug-1957, KD Snyder, D. De Foe, GSMNP; 7: Mt Buckley, 30-Jul-1959, KD Snyder, D. De Foe, GSMNP

South Dakota (Records for South Dakota may be either *B. occidentalis* or *B. terricola*): 3: Custer, 10-Jun-1927, O.A. Stevens, unknown, AMNH, gyne; 4: Custer, 9 mi N, 2-Sep-1952, LaBerge, unknown, KU; Pennington, 29-Jun-1962, F., P., & M. Rindge, unknown, AMNH, gyne; 3: Black Hills, Spearfish Creek, 2-Sep-1969, Mich, unknown, KU

Tennessee: Mt Leconte, 8-Sep-1934, W. King, R.R. Dreisbach, GSMNP; Mt Buckley, 8-Sep-1934, W. King, D. De Foe, GSMNP; 2: Alum Cave Trail (Mt Leconte), 31-Jul-1989, K. Langdon & J. Rock, S. Droege, GSMNP; Cades Cove, near Elijah Oliver home, 23-Sep-1999, A. Mayor & D. Paulsen, A.J. Mayor, GSMNP

Vermont: Nulhegan N'tl Wildlife Refuge, Brighton, 2-Jul-2006, M. Veit, M. Veit, Female, M. Veit

C. Bombus occidentalis museum records

CANADA

Alberta: (Records for Alberta may be either *B. occidentalis* or *B. terricola*) 4: unknown loc., 14-May-1890, Bean, unknown, AMNH, gyne; unknown loc., 10-Aug-1890, Bean, unknown, AMNH, male; unknown loc., 12-Jun-1893, Bean, unknown, AMNH, gyne; unknown loc., 16-May-1893, Bean, unknown, AMNH, gyne; unknown loc., 17-May-1893, Bean, unknown, AMNH, gyne; 9: Prairie Bluff Mt, 29-Jul-1971, Mich, unknown, KU; 6: High River, 35 mi. W, 5-Aug-1975, Mich, unknown, KU; Picture Butte, 3 mi SE, 14-Jun-1982, Mich, unknown, KU

British Columbia: unknown loc., 30-Apr-1924, unknown, unknown, AMNH, gyne; Lytton, 2-Aug-1931, Nott, unknown, KU; 2: Merritt, 3-Aug-1931, Beamer, unknown, KU; Merritt, 3-Aug-1931, Nott, unknown, KU; Kelowna, 5-Aug-1931, Nott, unknown, KU; Merritt, 6-Aug-1931, Anderson, unknown, KU; Merritt, 6-Aug-1931, Peters, unknown, KU; Vernon, 22-Jul-1932, leBlond, unknown, KU; Parksville Vancouver Island, 19-Aug, W.F. Barr, Strange, U of ID; Kootnay N'tl Park; Koots Crossing, 24-Aug,

H.C. Manis, Strange, U of ID; 2: Burns Bog, 19-Jul-1982, Mackenzie, unknown, KU; 4: Rutland, 2-May-1985, Fergusson, unknown, KU; 2: Rutland, 18-May-1985, Fergusson, unknown, KU; 3: Winfield, 18-May-1985, Fergusson, unknown, KU; Winfield, 23-May-1985, Fergusson, unknown, KU; Rutland, 26-Apr-1986, Fergusson, unknown, KU; 5: Nakusp, 97 km S of Revelstoke, 30-Jun-1988, Mich, unknown, KU; Shelter Bay, Revelstoke 48 km S, 30-Jun-1988, Mich, unknown, KU; Needles, 16 km S Revelstoke, 30-Jun-1988, Mich, unknown, KU; 4: Keremeos; 8 km N, 1-Jul-1988, Mich, unknown, KU; Princeton, 31 km S, 2-Jul-1988, Mich, unknown, KU; 2: Vancouver, 7-Jul-1988, Mich, unknown, KU

Saskatchewan (Record for Saskatchewan may be either *B. occidentalis* or *B. terricola*): Swift Current, 1-Aug-1971, Mich, unknown, KU; 6: Athabasca S.D.P.P., Thomas Bay, 17-Jul-2000, Brzoska, Brooks, KU

UNITED STATES OF AMERICA

Alaska: Yukon-Koyukuk, 12-May-1949, unknown, unknown, AMNH, gyne; Anchorage, 26-Jul-1954, Hunt, unknown, KU; Anchorage, 26-Jul-1954, Hunt, unknown, KU; Anchorage, 26-Jul-1954, Hunt, unknown, KU; Mt. Mckinley N'tl Pk, 19-Jun-1957, unknown, unknown, KU; Mt. Mckinley N'tl Pk, 19-Jun-1957, unknown, unknown, KU; Mt. Mckinley N'tl Pk, 19-Jun-1957, unknown, unknown, KU; Mt. Mckinley N'tl Pk, Tekianika River, 23-Jun-1957, Preston, unknown, KU; Mt. Mckinley N'tl Pk, 24-Jun-1957, unknown, unknown, KU; Mt. Mckinley N'tl Pk, 26-Jun-1957, unknown, unknown, KU; Mt. Mckinley N'tl Pk, 26-Jun-1957, unknown, unknown, KU; Mt. Mckinley N'tl Pk, 27-Jun-1957, unknown, unknown, KU; Seward, 22 mi N, 1-Jul-1957, Byers, unknown, KU; Seward, 23 mi. N; Hwy. 4, 1-Jul-1957, Byers, unknown, KU; 4: Anchorage, 15 mi SE, Seward Hwy., 3-Jul-1957, Preston, unknown, KU; 4: Matanuska-Susitna, 19-May-2003, L. Revet, unknown, AMNH, gyne

Arizona: 8: S. Arizona, Aug-1902, Snow, unknown, KU; 2: Flagstaff, 1-Aug-1933, Beamer, unknown, KU; Flagstaff, 5-Aug-1933, Beamer, unknown, KU; Coconino, 4-Aug-1934, P.E. Geier, unknown, AMNH; 7: Grand Canyon, North Rim, 13-Jul-1936, Rudkin, unknown, KU; Coconino, 15-Aug-1938, E.L. Bell, unknown, AMNH, male; Flagstaff, 8-Jul-1941, Beamer, unknown, KU; White Mts, 19-Jun-1950, Cook, unknown, KU; 2: San Francisco Mts, 25-Jun-1950, Wright, unknown, KU; Oak Creek Canyon, 26-Jun-1950, Wright, unknown, KU; Coconino, 12-Sep-1951, J.G. Rozen, unknown, AMNH, Male; 2: San Francisco Mts, 4-Jul-1952, Beamer, LaBerge & Liang, unknown, KU; 4: San Francisco Mts, 4-Jul-1952, Beamer, LaBerge, Weiner, Wolf & Liang, unknown, KU; Oak Creek Canyon, 9-Jul-1952, Beamer, LaBerge & Liang, unknown, KU; Fredonia, 10-Oct-1954, Goodarzy & Knowlton, unknown, KU; 3: San Francisco Mts, SW side, 12-Aug-1958, Alcorn, unknown, KU; Flagstaff, 8 mi N, 4 mi W, 13-Aug-1959, Alcorn, unknown, KU; Snow Bowl, 24-Aug-2002, L.E. Stevens, T. Griswold, USDA/USU, Male; Middle North Canyon Spring, 29-Jun-2004, L.E. Stevens, T. Griswold, USDA/USU; Kanabownits Meadow, 22-Jun-2005, L.E. Stevens, T. Griswold, USDA/USU; Lockett Meadow, SF Peaks, 20-Aug-2005, L.E. Stevens & M.H. Erhart, USDA/USU, male; Lockett Meadow, SF Peaks, 20-Aug-2005, L.E. Stevens & M.H. Erhart, , USDA/USU, Male; Interior Valley at Cabin, SFP, 20-May-2006, L.E. Stevens, T. Griswold, USDA/USU; San Francisco Peaks, 26-Jul-2006, R. England, T. Griswold, USDA/USU; Agassiz Tank, San Francisco Peaks, 31-Jul-2006, S. Till, T. Griswold,

USDA/USU; Snow Bowl, 1 km down, 14-May-2008, L.E. Stevens & M.H. Erhart, T. Griswold, USDA/USU, gyne; 1: Raspberry Spring, Inner Basin Trail, 5-Jul-2008, L.E. Stevens, T. Griswold, USDA/USU; 2: Raspberry Spring, Inner Basin Trail, 5-Jul-2008, L.E. Stevens, T. Griswold, USDA/USU, gyne; Inner Basin Trail, SFP, 5-Jul-2008, L.E. Stevens, T. Griswold, USDA/USU, gyne; 2: Inner Basin Trail, SFP, 8-Jul-2008, M.H. Erhart, T. Griswold, USDA/USU, gyne; Inner Basin Trail, SFP, 27-Aug-2008, E.G. North, T. Griswold, USDA/USU; 3: Inner Basin Trail, SFP, 27-Aug-2008, E.G. North, T. Griswold, USDA/USU, male

California: Sobre Vista, 9-May-1910, Kusche, unknown, KU; Sobre Vista, 6-Oct-1910, Kusche, unknown, KU; Millbrae, 1-Sep-1912, VanDyke, unknown, KU; Winters, 6-Aug-1929, Beamer, unknown, KU; Kern, 12-Jul-1931, E.O. Essig, unknown, AMNH; 2: Humboldt, 11-Jun-1935, E.O. Essig, unknown, AMNH, male; Eureka, 15-Jul-1935, Beamer, unknown, KU; 3: Berkeley, 27-Aug-1936, Mich, unknown, KU; Berkeley, 4-Sep-1936, Mich, unknown, KU; Antioch, 8-Sep-1936, Mich, unknown, KU; Antioch, 17-Nov-1939, Laningham, unknown, KU; Echo, 10-Aug-1940, Kenaga, unknown, KU; Contra Costa, 5-Apr-1952, J.D. Lattin, unknown, AMNH, gyne; Antioch, 16-Jun-1952, Beamer, unknown, KU; 3: Plumas, 7-Jul-1952, M.A. Cazier, W.J. Gertsch, R. Schrammel, unknown, AMNH; Concord, 16-Jun-1955, Opler, unknown, KU; Contra Costa, 8-Sep-1957, J.G. Rozen, unknown, AMNH; Berkeley, 5-Apr-1963, L.G. Bock, Strange, WSU, gyne; 8: Pt. Reyes, 24-Aug-1964, unknown, unknown, KU; Lafayette, 13-Feb-1968, L.G. Bock, Strange, WSU, gyne; 12: Joyce Island, 5-Oct-1975, Buchmann, unknown, KU; 2: Mad River Beach, 13-Jun-1976, Brooks, unknown, KU; 5: Arcata, 24-Jun-1976, Brooks, unknown, KU; Mad River Beach, 24-Jul-1976, Brooks, unknown, KU; 3: Quincy, 8 mi SW, 28-May-1977, Brooks, unknown, KU; Sagehen Creek, 4-Jun-1977, unknown, unknown, KU; 8: Bodega Bay, 10-Jul-1977, Brooks, unknown, KU; 10: Bodega Bay, 10-Aug-1977, Brooks, unknown, KU; 4: Bodega Bay, 13-Aug-1977, Brooks, unknown, KU; McClure Beach, Pt Reyes NS, 5-Jun-1978, Brooks, unknown, KU; 2: Antioch, 26-Sep-1978, Brooks, unknown, KU; 2: Arcata Lanphere-Christensen Dunes Preserve, 5mi NW, 28-Jun-1980, Brooks, unknown, KU; Viola 4 mi west, 21-May-1981, J.R. Fisher, Strange, WSU, gyne; Mad River Beach, 17-Jun-1982, Brooks, unknown, KU

Colorado: 25: Creede, Aug-1914, Hunter, unknown, KU; Boulder, 1-Aug-1924, N. LeVeque, unknown, AMNH, male; Pingree Park, Aug-1925, Beamer & Lawson, unknown, KU; Pingree Park, 21-Aug-1926, R.H. & L.D Beamer, unknown, KU; 4: Pingree Park, 23-Aug-1926, R.H. & L.D Beamer, unknown, KU; San Luis, 6-Jul-1933, unknown, unknown, KU; Boulder, 20-Aug-1935, Mich, unknown, KU; 2: Pingree Park, 22-Aug-1935, Mich, unknown, KU; Glenwood Springs, 10-Aug-1936, Beamer, unknown, KU; Glenwood Springs, 16-Aug-1936, Beamer, unknown, KU; Ouray, 1-Jul-1937, Johnston, unknown, KU; Mishawaka, 11-Jul-1937, Peters, unknown, KU; Craig, 2-Aug-1947, Mich, unknown, KU; Estes Park, near, 2-Jun-1948, Townes, unknown, KU; 2: Ohio, 4-Jul-1949, Beamer, unknown, KU; 2: Pingree Park, 6-Aug-1949, Beamer, unknown, KU; Poudre River, 6-Aug-1949, White, unknown, KU; Conejos Canyon, 17-Jul-1952, Grant, unknown, KU; 28: Boulder, 28-Jun-1953, Grant, unknown, KU; Durango, 7-Aug-1957, Mich, unknown, KU; Lyons, 9 mi NW, 16-Aug-1959, Ordway, unknown, KU; 2: Troublesome, 5 mi E, 17-Aug-1959, Ordway, unknown, KU; 2: Nederland, Ward; between, 29-Aug-1959, Ordway, unknown, KU; 2: Rocky Mtn. Nat'l Park, 40.0511°, -104.9825°, 8-Sep-1959, D.F. & J.C. Beneway, unknown, KU; 3:

Montrose, 5-Aug-1960, F., P., & M. Rindge, unknown, AMNH, male; 2: Montrose, 5-Aug-1960, F., P., & M. Rindge, unknown, AMNH; 4: Montrose, 6-Aug-1960, F., P., & B. Rindge, unknown, AMNH; 4: Montrose, 7-Aug-1960, F., P., & B. Rindge, unknown, AMNH; Gunnison, 8-Aug-1961, F., P., & J. Rindge, unknown, AMNH, gyne; Lake Granby, Stillwater Campgrounds, 29-Aug-1962, Kerfoot, unknown, KU; Garfield, 31-Jul-1963, F., P., & M. Rindge, unknown, AMNH; Coaldale; 6 mi S, 10-Aug-1964, Mich, unknown, KU; Gothic, 07-00-1964, Michener & Downhower, unknown, KU; Gothic, Jul-1964, Michener & Downhower, unknown, KU; Lake George, 20-Aug-1965, Byers & Atchley, unknown, KU; Grand, 26-Jul-1967, F., P., & M. Rindge, unknown, AMNH, gyne; Larimer, 19-Aug-1967, M. Statham, unknown, AMNH, gyne; 2: Coaldale, 5 mi S, 13-Aug-1969, Mich, unknown, KU; Coaldale, 5 mi S, 8-Jul-1970, Brothers & Michener, unknown, KU; Poncha Pass, 12-Jul-1970, Mich, unknown, KU; Larimer, 8-Aug-1974, M. & T.M. Favreau, unknown, AMNH, male; Dolores, 24-Jul-1976, N.L. Herman, unknown, AMNH; Mesa Verde Nat'l Park, 16-Jul-1978, Burtchett, unknown, KU; 3: Michigan River, Walden, 19-Jul-1981, Byers & Teale, unknown, KU; Tabernash Campground, 5 mi. S of Granby, 20-Jul-1981, Byers & Teale, unknown, KU; Wolf Creek Pass, US Highway #160, 25-Jul-1981, Teale, unknown, KU; Boulder, 3 mi W, 11-Aug-1982, Mich, unknown, KU

Idaho: 3: Coolin Priest Lake, 19-Jul-1927, VanDyke, unknown, KU; Lowman, 30-Jul-1927, Cady, unknown, KU; Bear Lake, 7-Aug-1949, W.J. Gertsch & J.W. Gertsch, unknown, AMNH; Potlach, 12-Oct-1953, R.H. Abbot, Strange, U of ID; 2: Cub River Canyon, 28-Aug-1954, Knowlton, unknown, KU; Cub River Canyon; Thomas Springs, 28-Aug-1954-1954, Knowlton, unknown, KU; Moscow, 12-Jun-1960, R.W. Portman, Strange, U of ID, gyne; 11: Gibbonsville, 28-Aug-1960, H.C. Manis, Strange, U of ID, male; 11: Gibbonsville, 28-Aug-1960, H.C. Manis, Strange, U of ID, male; Franklin, 25-Jul-1964, Knowlton, unknown, KU; 5 mi N North Fork, 25-Jul-1965, R.L. Westcott, Strange, U of ID; Lolo Pass, 10-Aug-1965, L.S. Hawkins, Strange, U of ID; 3: 5 mi N North Fork, 31-Aug-1965, R.L. Westcott, Strange, U of ID; 3: 5 mi N North Fork, 31-Aug-1965, R.L. Westcott, Strange, U of ID, male; 2: 30 mi S Lolo Pass, 31-Aug-1965, R.L. Westcott, Strange, U of ID; 5 mi N North Fork, 1-Sep-1965, R.L. Westcott, Strange, U of ID; Cave Lake, 5-May-1966, M.A. Brusven, Strange, U of ID, gyne; 3.8 mi N Georgetown, 18-Jul-1966, A.R. Gittins, Strange, U of ID; 9: 8 mi S Cobalt, 6-Sep-1967, L.S. Hawkins, Strange, U of ID; 16: 8 mi S Cobalt, 6-Sep-1967, L.S. Hawkins, Strange, U of ID, male; 10 mi SW Samuels; Pack River Cyn, 27-Sep-1969, A.R. Gittins, Strange, U of ID, male; Laird Park; 3 mi SE Harvard, 2-Apr-1971, W.J. Turner, Strange, WSU, gyne; 6 mi N Moscow, 22-Apr-1971, W.J. Turner, Strange, WSU, gyne; 6 mi N Moscow, 7-May-1971, W.J. Turner, Strange, WSU, gyne; Twin Falls ID, 15-Jun-1971, A.L. Antonelli, Strange, U of ID, gyne; U of ID Moscow, 21-Apr-1972, G.W. Ulrich, Strange, U of ID, gyne; Laird Park; 4 mi NE Harvard, 25-Mar-1973, D.P. Corredor, Strange, WSU, gyne; Laird Park; 4 mi NE Harvard, 13-May-1973, D.P. Corredor, Strange, WSU, gyne; Roberson Lake, Moscow, 6-May-1974, J. L. Baker, Strange, U of ID, gyne; 2 mi E Round Lake, 21-Aug-1976, unknown, Strange, U of ID; Granite Lake, 28-Jul-1977, S.T. Rose, Strange, U of ID; Moscow, 21-Mar-1980, R. Sprague, Strange, U of ID, gyne; 3: 1 mi S Fernwood, 8-Jul-1987, R.S. Zack, Strange, WSU; Oneida, 18-Jun-1998, J.G. Rozen, unknown, AMNH, gyne; Custer Co., 28-Jul-1997, K. Donham, Schroeder, SOU; 2: Valley Co., 31-Jul-1997, K. Donham, Schroeder, SOU

Montana (Records for Montana may be either *B. occidentalis* or *B. terricola*): 3: Beaver Creek, 1-Aug-1913, Hunter, unknown, KU; Avalanche Creek, Glacier N'tl Pk, 12-Jul-1920, Nast, unknown, KU; Haugan, 9-Aug-1931, Anderson, unknown, KU; 3: Haugan, 9-Aug-1931, Beamer, unknown, KU; Haugan, 9-Aug-1931, Nott, unknown, KU; Haugan, 9-Aug-1931, Peters, unknown, KU; 2: Missoula, 11-Aug-1931, Nott, unknown, KU; Missoula, 11-Aug-1931, Sanderson, unknown, KU; 3: Bozeman, 13-Aug-1931, Beamer, unknown, KU; 2: Bozeman, 13-Aug-1931, Nott, unknown, KU; Hamilton, 17-Jul-1949, Beamer, unknown, KU; Como Lake, 17-Jul-1949, Beamer, unknown, KU; Como Lake, 17-Jul-1949, White, unknown, KU; 2: Skalkaho Pass, Hamilton, 19-Jul-1949, Beamer, unknown, KU; Skalkaho Pass, Hamilton, 1-Aug-1949, White, unknown, KU; Skalkaho Pass, 2: near Hamilton, 1-Aug-1949, White, unknown, KU; Lost Horse Canyon, Hamilton, 2-Aug-1949, Beamer, unknown, KU; Lost Horse Canyon, Hamilton, 2-Aug-1949, White, unknown, KU; Hamilton, 9-Jun-1956, Miura, unknown, KU; 1.7 mi E Below Summit Bannock Pass, 20-May-1956, unknown, Strange, U of ID, gyne; Pintlar Meadow, 22-Jul-1957, D. Cox, Strange, WSU, gyne; Ekalaka, 7 mi. S; Custer N'tl Forest, 9-Aug-1967, Hepburn, unknown, KU; Florence; near, 10-Jun-1980, Yanega, unknown, KU; Monarch; 8 mi N, 19-Jun-1982, Mich, unknown, KU; McGregor Lake, Kalispell, 57 km W from, 3-Jul-1982, Brooks, unknown, KU

New Mexico: 2: Catron, 11-Jul-1961, F., P., & J. Rindge, unknown, AMNH

Oregon: 2: Haines, 10-Jul-1931, Beamer, unknown, KU; Anthony Lake, 11-Jul-1931, Anderson, unknown, KU; North Powder, 13-Jul-1931, Nott, unknown, KU; Arlington, 15-Jul-1931, Sanderson, unknown, KU; Hood River, 17-Jul-1931, Anderson, unknown, KU; Hood River, 17-Jul-1931, Nott, unknown, KU; Mt. Hood, 18-Jul-1931, Beamer, unknown, KU; Florence, 11-Jul-1935, Beamer, unknown, KU; Waldport, 11-Jul-1935, Beamer, unknown, KU; Hecita, 11-Jul-1935, Russell, unknown, KU; 2: Grants Pass, 12-Jul-1935, Beamer, unknown, KU; Klamath, 3-Jul-1952, M.A. Cazier, W.J. Gertsch & R. Schrammel, unknown, AMNH, male; Jackson Co., 24-Jul-1967, unknown, Schroeder, SOU; Jackson Co., 25-Jun-1975, M. Cogswell, Schroeder, SOU, gyne; Jackson Co., 30-Jun-1975, C. Matthews, Schroeder, SOU; 2: Bandon, 5-Jul-1976, Brooks, unknown, KU; 2: U. Goose Creek 34mi. SE Union 4160 ft, 28-Jun-1976, Davis, Strange, WSU, gyne; L. Lick Creek 26 mi. SE Union 4280 ft, 28-Jun-1976, Davis, Strange, WSU; Velvet Creek 28 mi SE Union 4720 ft, 2-Jul-1976, Davis, Strange, WSU; U. Goose Creek 34mi. SE Union 4160 ft, 2-Jul-1976, Davis, Strange, WSU; L. Goose Creek 36mi. SE Union 4000ft, 2-Jul-1976, Davis, Strange, WSU; 2: Big Creek 26 mi SE Union 4200ft, 12-Jul-1976, Davis, Strange, WSU, OR ; U. Goose Creek 34mi. SE Union 4160ft, 13-Jul-1976, Davis, Strange, WSU; Big Creek 26 mi SE Union 4200ft, 28-Jul-1976, Davis, Strange, WSU; Ladd Canyon, 14 mi S La Grande 4280ft, 30-Jul-1976, Davis, Strange, WSU; 2: L. Lick Creek 26 mi. SE Union 4280ft, 23-Aug-1976, Davis, Strange, WSU; Jordan Creek 28 mi. SSW La Grande 4840ft., 30-Aug-1976, Davis, Strange, WSU; 2: Velvet Creek 28 mi SE Union 4720ft, 8-Jul-1977, Davis, Strange, WSU; Ladd Canyon, 14 mi S La Grande 4280ft, 8-Jul-1977, Davis, Strange, WSU; 2: U. Lick Cr. 28 mi SE Union 42800ft, 8-Jul-1977, Davis, Strange, WSU, gyne; Ladd Canyon, 14 mi S La Grande 4280ft, 9-Jul-1977, Davis, Strange, WSU; Velvet Creek 28 mi SE Union 4720ft, 17-Jul-1977, Davis, Strange, WSU; U. Lick Cr. 28 mi SE Union 4920ft, 17-Jul-1977, Davis, Strange, WSU; Velvet Creek 28 mi SE Union 4720ft, 24-Jul-1977, Davis, Strange, WSU; Ladd Canyon, 14 mi S La Grande 4280 ft, 29-Jul-1977, Davis, Strange, WSU, male; U.

Lick Cr. 28 mi SE Union 4280 ft, 3-Aug-1977, Davis, Strange, WSU; Ladd Canyon, 14 mi S La Grande 4280ft, 13-Aug-1977, Davis, Strange, WSU; Velvet Creek 28 mi SE Union 4720ft, 21-Aug-1977, Davis, Strange, WSU; Big Creek 26 mi SE Union 4200 ft, 21-Aug-1977, Davis, Strange, WSU; Ashland, 1-Oct-1979, R. Nordquist, Schroeder, SOU, male; Talent, 15-Oct-1979, R. Nordquist, Schroeder, SOU, gyne; Gold Hill, 1-Jul-1988, L. A. Ashpole, Schroeder, SOU; Cresswell, 1-Sep-1991, B. Conway, Schroeder, SOU, gyne; Ashland, 1-Sep-1991, G. Craig, Schroeder, SOU; Jackson Co., 19-Sep-1991, Vanette West, Schroeder, SOU, male; Central Point, 1-Oct-1991, K. Spies, Schroeder, SOU; Ashland, 1-Sep-1992, G.E. Zimmerman, Schroeder, SOU, male; Douglas Co., 1-Oct-1994, R. Gordon, Schroeder, SOU, gyne; Jackson Co., 10-Oct-1995, Shane Settle, Schroeder, SOU; Ashland, 12-Apr-1997, C. Ferguson, Schroeder, SOU, gyne; Medford, 25-May-1997, P. Schroeder, Schroeder, SOU, gyne; 2: Ashland, 8-Jun-1997-, C. Ferguson, Schroeder, SOU; Ashland, 8-Jun-1997, C. Ferguson, Schroeder, SOU; Shale City, 10-Jun-1997, C. Ferguson, Schroeder, SOU; 2: Ashland, 14-Jun-1997, C. Ferguson, Schroeder, SOU; 3: Jackson Co., 13-Jul-1997, K. Donham, Schroeder, SOU; Ashland, 15-Aug-1997, C. Ferguson, Schroeder, SOU, gyne; Shale City, 21-Aug-1997-, C. Ferguson, Schroeder, SOU, male; Shale City, 21-Aug-1997, C. Ferguson, Schroeder, SOU; Jackson Co., 21-Aug-1997, K. Donham, Schroeder, SOU, male; 3: Jackson Co., 21-Aug-1997, K. Donham, Schroeder, SOU, male; Jackson Co., 25-Aug-1997, B. Fields, Schroeder, SOU; 2: Crater Lake N.P., 1-Sep-1997, C. Ferguson, Schroeder, SOU; Jackson Co., 1-Sep-1997, K. Donham, Schroeder, SOU; Josephine Co., 31-May-1998, C. Ferguson, Schroeder, SOU, gyne; Jackson Co., 6-Jun-1998, C. Ferguson, Schroeder, SOU, gyne; Jefferson Co., 24-Jul-1998, P. Schroeder, Schroeder, SOU

South Dakota (Records for South Dakota may be either *B. occidentalis* or *B. terricola*):

3: Custer, 10-Jun-1927, O.A. Stevens, unknown, AMNH, gyne; 4: Custer, 9 mi N, 2-Sep-1952, LaBerge, unknown, KU; Pennington, 29-Jun-1962, F., P., & M. Rindge, unknown, AMNH, gyne; 3: Black Hills, Spearfish Creek, 2-Sep-1969, Mich, unknown, KU

Utah: Cove Fort, 14-Aug-1929, Anderson, unknown, KU; 3: Cove Fort, 14-Aug-1929, Oman, unknown, KU; Salt Lake City, 3-Jul-1931, Anderson, unknown, KU; Kavab, 12-Jul-1936, Rudkin, unknown, KU; 2: Hanna, 14-Jul-1949, Beamer, unknown, KU; 2: Garfield, 9-Aug-1950, T. Cohn, P. Boone & M.A. Cazier, unknown, AMNH, male; Garfield, 9-Aug-1950, T. Cohn, P. Boone & M.A. Cazier, unknown, AMNH; Summit, 25-Sep-1953, M.A. Cazier, unknown, AMNH, male; 2: Blacksmith Fork Canyon, 2-Sep-1955, Hanson, unknown, KU; Logan, 3-Sep-1955, Hanson, unknown, KU; 6: Allen Canyon, 29-Aug-1956, Knowlton, Hanson & Nielson, unknown, KU; 2: Orderville, 12-Aug-1957, Mich, unknown, KU; Salt Lake, 24-Jun-1958, W.J. Gertsch & J.W. Gertsch, unknown, AMNH, gyne; Sanpete, 3-Aug-1958, F., P., & J. Rindge, unknown, AMNH; Logan Canyon, 9.7 km NE Logan, 9-Jun-1959, Byers, unknown, KU; Logan Canyon, 5 mi. S, 18-Aug-1959, Ordway, unknown, KU; 2: Tooele, 2-Jul-1960, F., P., & B. Rindge, unknown, AMNH, gyne; 3: Beaver, 16-Jul-1960, F., P., & B. Rindge, unknown, AMNH; 7: Beaver, 17-Jul-1960, F., P., & B. Rindge, unknown, AMNH; 2: Grand, 29-Jul-1960, F., P., & B. Rindge, unknown, AMNH, male; 5: Grand, 1-Aug-1960, F., P., & B. Rindge, unknown, AMNH, male; 2: Grand, 1-Aug-1960, F., P., & B. Rindge, unknown, AMNH; Grand, 2-Aug-1960, F., P., & B. Rindge, unknown, AMNH; Grand, 3-Aug-1960, F., P., & B. Rindge, unknown, AMNH; Logan Canyon, 23-Jul-1961, Knowlton, unknown, KU; Provo, 6-Apr-1962, N.M. Jorgensen, Strange, WSU, gyne; Wasatch, 6-May-1963, D.H.

Huntzinger, unknown, AMNH, gyne; Uintah, 28-Jul-1963, F., P., & M. Rindge, unknown, AMNH; Wasatch, 30-Aug-1964, D.H. Huntzinger, unknown, AMNH, gyne; Tooele, 14-Jun-1998, J.G. Rozen, unknown, AMNH, gyne

Washington: Mt Ranier, 12-Aug-1927, Stephenson, unknown, KU; Kalama R., 21-Jul-1931-1931, Beamer, unknown, KU; 2: Montesano, 23-Jul-1931, Nott, unknown, KU; 2: Copalis, 25-Jul-1931, Nott, unknown, KU; Arlington, 28-Jul-1931, Beamer, unknown, KU; Conway, 28-Jul-1931, Nott, unknown, KU; Conway, 28-Jul-1931, Peters, unknown, KU; 3: Republic, 6-Aug-1931, Nott, unknown, KU; 6: Republic, 6-Aug-1931, Peters, unknown, KU; Kalama, 4-Jul-1935, Russell, unknown, KU; Satus Pass, 9-Jul-1935, Beamer, unknown, KU; 4: Colokum Pass, 21-Jul-1949, Beamer, unknown, KU; Colokum Pass, 21-Jul-1949, White, unknown, KU; Packwood, 22-Jul-1949, Beamer, unknown, KU; Gardiner, 24-Jul-1949, Beamer, unknown, KU; Shelton, 24-Jul-1949, White, unknown, KU; American river, 29-Jul-1949, Beamer, unknown, KU; 3: Harstine Island, 23-Jun-1950, G.S. Batchelor, Strange, WSU; Haeder Ranch, Pullman, 26-Jul-1950, H.S. Telford, Strange, WSU; Pullman, 3-Aug-1953, Bede & Okigbo, Strange, WSU; Wawawai, 6-Aug-1957, R. Alvarado, Strange, WSU; Chehalis, 9-Aug-1957, C. Johansen, Strange, WSU, male; Colfax, 11-May-1958, P.E.K. Shephard, Strange, WSU, gyne; 14: Chehalis vicinity of, 25-Jul-1958, C. Johansen, Strange, WSU; Pullman, 15-Apr-1961, B. Finnegan, Strange, WSU, gyne; Stevens, 1-May-1962, W. Ivie, unknown, AMNH, gyne; Pullman, 10-Jun-1962, R.W. Dawson, Strange, WSU; 5: Illahee, 11-Jul-1962, D. Frechin, Strange, WSU; Pullman, 13-Jun-1964, H.R. Dodge, Strange, WSU; Doebay; Orcas Island, 15-Aug-1964, A.R. Gittins, Strange, U of ID, male; Pullman, 10-Aug-1965, R.D. Akre, Strange, WSU; Pullman, 11-Aug-1965, R.D. Akre, Strange, WSU; 5: Sappho, 19-Jun-1966, B.A. Freeman, Strange, WSU; Richland, 1-Jul-1967, P.J. Gage, Strange, WSU, gyne; Pullman, 2-Aug-1969, R.W. Dawson, Strange, WSU, gyne; Hoodspport, 5-Aug-1969, D. James, Strange, WSU; Hoodspport, 5-Aug-1969, D. James, Strange, WSU, male; Spokane, 4-May-1970, M. Wiebers, Strange, WSU, gyne; Spokane, 15-Aug-1970, unknown, Strange, WSU,; Pullman, 15-Apr-1971, T. Mahary, Strange, WSU, gyne; Wawawai, 16-May-1971, T. Mahary, Strange, WSU, gyne; 2: Field Springs St Park, , 7-Jun-1971, M. Wiebers, Strange, WSU; Wallapa Bay nr. Nahcotta, 13-Jun-1971, D.N. Ferro, Strange, WSU; Ft. Worden nr Port Townsend, 16-Jun-1971, W.J. Turner, Strange, WSU, gyne; 3: Ft. Worden nr Port Townsend, 16-Jun-1971, W.J. Turner, Strange, WSU; Rockport St Psrk, 7 mi E of Concrete, 17-Jun-1971, W.J. Turner, Strange, WSU; Squilchuck, 25-Jul-1971, J. Brunner, Strange, WSU; 7: Field Springs St Park, 1-Aug-1971, W.J. Turner, Strange, WSU; 3: Field Springs St Park , 1-Aug-1971, W.J. Turner, Strange, WSU, male; Kamiak Butte 5 mi S of Palouse, 22-Aug-1971, R.F. Lagier, Strange, WSU; 6 mi SW Hoh River; Hoh River, 5-Aug-1972, W.J. Turner, Strange, WSU; Almota, 18-Feb-1973, R.E. Jenkins, Strange, WSU; WSU Golf Course, Pullman, 4-May-1973, D. A. Honebrink, Strange, WSU, gyne; 1 mile above end White River Rd, 5-Aug-1973, J. Logan, Strange, WSU; 5 mi E White River Campground Mt Rainier Nat'l Park 5000 ft, 23-Aug-1973, W.J. Turner, Strange, WSU; 2: Tenino, 2-May-1974, D. Frechin, Strange, WSU, gyne; 3: Tenino, 5-May-1974, D. Frechin, Strange, WSU, gyne; Tenino, 26-May-1974, D. Frechin, Strange, WSU; Tenino, 26-May-1974, D. Frechin, Strange, WSU, gyne; Tenino, 15-Jun-1974, D. Frechin, Strange, WSU, gyne; Pullman, 10-May-1975, A. Voyadjoglou, Strange, WSU, gyne; Richland, 10-May-1976,

N.E. Woodley, Strange, WSU; Richland, 12-May-1976, N.E. Woodley, Strange, WSU; Richland, 14-May-1976, N.E. Woodley, Strange, WSU, gyne
; 2: Richland, 14-May-1976, N.E. Woodley, Strange, WSU; 2: Mt Spokane St Park; nr. Bals Knob Campground; 5200ft, 7-Jul-1976, W.J. Turner, Strange, WSU; SCS Pond WSU Campus; Pullman, 7-Apr-1977, R.S. Zack, Strange, WSU, gyne; Grand Ronde Canyon; 8 mi below state park, 10-Apr-1977, J. Phillips, Strange, WSU, gyne; Bald Knob Campground, Mt. Spokane SP 4800-5200 ft, 25-Jul-1978, W.J. Turner, Strange, WSU, gyne; Wenatchee 670-800 ft, 11-May-1981, unknown, Strange, WSU, gyne; 3: Thornton Creek, Seattle, 3-Mar-1984, D. Frechin, Strange, WSU, gyne; Sultan Basin, 24-Jun-1985, D. Frechin, Strange, WSU, gyne; Concrete, 8-Jul-1988, Mich, unknown, KU
Wyoming: Moran, 10-Jun-1935, Lindsay, unknown, KU; Lincoln, 12-Aug-1949, W.J. & J.W. Gertsch, unknown, AMNH, male; Big Horn, 5-Jul-1952, Lawson, unknown, KU; Big Horn, 10-Jul-1953, Lawson, unknown, KU; Big Horn, 12-Jul-1958, unknown, unknown, KU; 5: Crook, 4-Jul-1962, F., P., & M. Rindge, unknown, AMNH; 13: Crook, 5-Jul-1962, F., P., & M. Rindge, unknown, AMNH; 5: Crook, 9-Jul-1962, F., P., & M. Rindge, unknown, AMNH; 2: Crook, 10-Jul-1962, F., P., & M. Rindge, unknown, AMNH, gyne; Sheridan, 15-Jul-1962, F., P., & M. Rindge, unknown, AMNH; Park, 28-Jul-1962, F., P., & M. Rindge, unknown, AMNH; 6: Sublette, 11-Aug-1962, J.G. & B.L. Rozen, unknown, AMNH; Dubois; 32 km NW, 15-Jun-1988, Mich, unknown, KU

XI. APPENDIX II

This appendix contains an itemized list of museum collections that are known or expected to have significant collections of bumble bees. A comprehensive review of all of the *B. affinis*, *B. terricola* and *B. occidentalis* specimens in each of these museum collections would enhance our understanding of the historic of these bumble bees.

Museum	Institution	Area	Collectors or Curators
Essig Museum of Entomology	University of California, Berkeley	W	Linsley, MacSwain, Hurd, Daly, Thorp
Bohart Museum of Entomology	University of California, Davis	W	Bohart, Kimsey, Thorp
	California State University, Humboldt	W	Mesler, Gordon, Nyoka, M Brooks
Los Angeles County Museum	Los Angeles County Museum	W	Snelling
	University of California, Riverside	W	Timberlake, Yanega
California Academy of Sciences	California Academy of Sciences	W	
United States National Pollinating Insect Collection	Bee Biology and Systematics Laboratory	W	Bohart, Parker, Torchio, Griswold
Oregon State Arthropod Collection	Oregon State University	W	Scullen, Stephen
	University of Colorado, Boulder	W	Cockerell, Lanham, Macior, Byron
Gillette Arthropod Biodiversity Museum	Colorado State University	W	Evans
James Entology Collection	Washington State University, Pullman	W	Johansen Zack
Peabody Museum of Natural History	Yale University	E	
Department of Ecology and Evolutionary Biology	University of Connecticut	E	Stage
United States National Museum	Smithsonian Institution	E/W	Hurd, Stage, Macior
W.F. Barr Entomology Collection	University of Idaho	W	Merickel
	Southern Illinois University	E	Robertson
Illinois Natural History Survey	Illinois Natural History Survey	E/W	Frison, LaBerge, Cameron
Field Museum of Natural History	Field Museum of Natural History	E	
	Purdue University	E	Chandler, Hazeltine
Snow Museum of Entomology	University of Kansas	E	Michener, R Brooks, Engle
	University of Maine	E	
Museum of Comparative Zoology	Harvard University	E	Bequart, Evans
	University of Michigan	E	Milliron, Thorp

	Michigan State University	E	Fisher, Driesbach, Strickler
	University of Minnesota	E	Reed, Evans
	Montana State University	W	
Nebraska State Museum	University of Nebraska	E	LaBerge, Webb, Ellis
	University of Nevada, Reno	W	Rust?
	University of New Hampshire	E	
	Rutgers University	E	Roberts
	Princeton University	E	
	Cornell University	E	Eickwort, Ascher, Danforth
American Museum of Natural History	American Museum of Natural History	E	Rozen, Ascher
	North Carolina State University	E	Mitchell
	North Dakota State University	E	
	Ohio State University	E	
Philadelphia Academy of Natural Sciences	Philadelphia Academy of Natural Sciences	E	
Carnegie Museum of Natural History	Carnegie Museum of Natural History	E	Milliron?
	University of Vermont	E	Heinrich
	University of Wisconsin	E	Medler, Fye
	Bernice P. Bishop Museum	E	Medler?
	Lethbridge Res Station	W	Hobbs, Richards
Spencer Museum	University of British Columbia	W	
Canadian National Collection	Canadian National Collection	E/W	Milliron
Laurence Packer Bee Coll, Department of Biology	York University	E	Packer, Colla
Biology Department	Calgary University	W	Harder, Owen
Department of Zoology	University of Western Ontario	E	Lavery
Department of Ecology and Evolutionary Biology	University of Toronto	E	Plowright, Thomson, Otterstatter, Gegeer
Royal Ontario Museum	Royal Ontario Museum	E	
Department of Entomology	Natural History Museum	E/W	Williams, Brown