Importation of Non-Native Bumble Bees into North America:

Potential Consequences of Using *Bombus terrestris* and Other Non-Native Bumble Bees for Greenhouse Crop Pollination in Canada, Mexico, and the United States

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A White Paper of the

North American Pollinator Protection Campaign (NAPPC)

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PURPOSE

The North American Pollinator Protection Campaign (NAPPC), with funding from the CS Fund, has produced this white paper about the status and potential effects of non-native bumble bees, such as *Bombus terrestris,* on native populations of bumble bees and other pollinators. This project is a response to questions raised by scientists and policymakers in North America following the initial importation of the European bumble bee species, *Bombus terrestris*, to Mexico for greenhouse tomato production. In this paper, we describe the physical and behavioral characteristics of *Bombus terrestris*, discuss reports of suggested impacts on native species and ecosystems caused by the spread of exotic bumble bee populations in countries engaged in commercial importation, and review the potential consequences of introducing and expanding populations of non-native bumble bees into Canada, Mexico, and the United States. We also present the opinions and recommendations of NAPPC with regard to present and future regulations and management of *Bombus* species as commercial pollinators in North America.

SUMMARY

This white paper by the North American Pollinator Protection Campaign (NAPPC) describes the effects (potential and realized) of importing non-native bumble bees, such as *Bombus terrestris,* on native populations of bumble bees and other pollinators. Bumble bees are among the most important pollinators of temperate zone plants because of their diverse body and proboscis sizes, ability to sonicate, dense pile, long activity periods, and adaptability to a wide variety of temperatures and climate types. Two primary species of bumble bee are reared commercially for greenhouse tomato (*Lycopersicon esculentum*) pollination, including *Bombus terrestris*, a widely distributed native of Europe, coastal North Africa, and West and Central Asia; and *Bombus impatiens*, a native of North America. Almost one million colonies of primarily *B. terrestris* and *B. impatiens* are reared annually in commercial facilities, largely for use in greenhouse tomato production, a multi-billion dollar industry worldwide.

In some countries where it has already been imported for commercial crop pollination, populations of *Bombus terrestris* have become naturalized and have expanded their ranges. In new environments, *B. terrestris* may threaten populations of native pollinators by introducing new diseases, displacing natives through competition for resources, or disrupting genetic adaptations by hybridizing with native species.
The North American continent hosts over 4,000 species of native bees, including fifty-four species of native *Bombus*. Native bumble bees face threats from introduced parasites and diseases, including *Nosema bombi*, the microorganism *Crithidia bombi,* the tracheal mite *Locustacarus* (= *Bombacarus*) *buchneri*, and hymenopteran brood parasitoids such as *Melittobia acasta* and *M. chalybii* , which can be difficult to detect when inspecting commercial colonies and may be spread from commercial to wild colonies by greenhouse production facilities.

Most of the ten subspecies of *Bombus terrestris* have been utilized in areas outside of their natural range, and may potentially threaten co-evolved plant-pollinator relationships and habitats. These risks have prompted several governments, including the Canary Islands, Norway, Japan, China, South Africa, New South Wales, and Australia, to impose restrictions on the importation of some subspecies of *B. terrestris*.

These written restrictions, NAPPC's tri-national network of experts in the field of pollination ecology, and the written recommendations of this paper (please see pages 22-24) serve as resources for policymakers in Mexico, Canada, and the United States, and across the globe.

BACKGROUND

Native pollinators provide essential reproductive services for wild and cultivated plants in virtually all terrestrial ecosystems. Bumble bees, in particular, are among the most important pollinators of temperate zone plants (Proctor, Yeo, and Lack 1996). The dense hairs on the bodies of bumble bees allow efficient pollen transfer from flower to flower. Bumble bees can also sonicate (buzz pollinate) wildflowers and crops (including tomato) whose flowers shed pollen through apical pores (Buchmann 1983). Five species of bumble bees are used for commercial crop pollination: *Bombus terrestris, B. lucorum, B. occidentalis, B. ignitus*, and *B. impatiens.* Of these, two bumble bee species have the most prominent role: *Bombus terrestris*, a widely distributed native of Europe, coastal North Africa, and West and Central Asia; and *Bombus impatiens*, a native of North America (Velthuis and van Doorn 2006). *Bombus terrestris* has been favored in commercial rearing for its wide distribution, large colony production, and adaptability to artificial conditions (Velthuis and van Doorn 2006). This species has been used extensively for agricultural crop pollination since the late 1980s, primarily within Europe initially, but ultimately by over 15 countries, including those where *Bombus terrestris* is not native - such as New Zealand and Japan. Its adaptability to diverse climatic conditions, habitats, and flower types makes it a hardy and efficient pollinator.

In some countries where this species has already been imported for commercial crop pollination, populations of *Bombus terrestris* have become naturalized and have expanded their ranges, exploiting floral resources and potentially competing with other pollinators, including native bees. Concern continues to grow about the effects of invasive *B. terrestris* on native pollinators and their established relationships with local plants in native ecosystems. In new environments, *B. terrestris* may threaten populations of native pollinators by introducing new diseases, displacing natives through competition for resources, or disrupting genetic adaptations by hybridizing with native species.

Despite concerns emanating from negative experiences where *B. terrestris* has been introduced and regulations set in place to prohibit its importation into the United States and Canada, shipments of *B. terrestris* were allowed into Jalisco, Mexico, in 1995 and 1996 for greenhouse tomato pollination (Golubov, pers. comm.). Although importation of additional colonies was subsequently prevented, pressure persists to allow *B. terrestris* into Canada, Mexico, and the United States for greenhouse use. An immediate evaluation of its dispersal, effects on native pollinators and ecosystems, and potential threat to neighboring countries is required in order to prioritize actions to prevent negative consequences and to identify alternatives to the importation of a non-native species into North America.

CHARACTERISTICS OF *BOMBUS* SPECIES

Bumble bees exhibit a tremendous variation in body size and proboscis (tongue) length, and forage on a variety of floral resources. Most bumble bees have longer tongues than honey bees, allowing them to reach nectar even in deep, tubular flowers. They also exhibit a distinctive behavior of sonication, or "buzz pollination," that vibrates pollen from the poricidal anthers of plants such as tomatoes (Buchmann 1983). Bumble bees rapidly contract their indirect flight muscles while curled around a tomato flower androecium -- a behavior which turns the bees into "living tuning forks" that transmit vibrations into a flower's anthers, resulting in rapid pollen ejection from its apical pores. Bumble bees can harvest pollen from "buzzed" tomato flowers 400 times faster than honey bees can. Whereas managed honey bees are also generalists that can pollinate a wide variety of native plants and managed crops, they are less efficient and more temperature-restricted than bumble bees for many crops (Free and Butler 1959, Holm 1966a, Alford 1975, Prys-Jones and Corbet 1991, Goulson 2003, Pouvreau 2004, Velthuis and van Doorn 2006), and due to their inability to use sonication to collect pollen, are not as useful for tomato pollination.

Bumble bees are adapted to a diversity of climates and habitats, and are active even when light intensity is low. Because of their relatively large body sizes and dense pile, they are able to continue foraging even at temperatures as low as 10˚ Celsius and as high as 32˚C, with observations of *B. t. dalmatinus* at temperatures as low as 2˚C (Ings, pers. comm.). Their increased motility allows them to continue flower visits for most of the year, unlike honey bees, which are mostly inactive at temperatures below 16˚C (Heinrich 1979). Bumble bees can forage during adverse climatic conditions, even flying during light rain, visiting from 20-50 flowers per minute with high pollination efficiency. Several species of *Bombus*, including *B. affinis,* emerge early in the spring and forage into the cool fall weather of November (Laverty and Harder 1988). Consequently, many early spring and late fall flowering plants benefit from pollination services provided by members of this hardy genus.

The five commercially reared species of *Bombus*, including *B. (Bombus) terrestris, B. (B.) lucorum, B. (B.) occidentalis, B. (B.) ignitus*, and *B. (Pyrobombus) impatiens*, belong to two closely related subgenera, *Bombus* and *Pyrobombus*, which are "pollen storers." These species store provisions of pollen near the brood cells in order to feed larvae, and are particularly useful as managed pollinators. In contrast, the more distantly related "pocket maker" bumble bees such as *B. (Megabombus) hortorum, B. (Thoracobombus) pascuorum, B. (Thoracobombus) ruderarius*, and *B. (Diversobombus) diversus* (Kawakita et al. 2004) have brood cells with a "pocket" adjoining a brood clump that contains pressed pollen available directly to the developing larvae (Velthuis and van Doorn 2006). Pollen storing species respond more positively to greenhouse rearing conditions, where pollen may be supplied in bulk amounts for workers to administer to larvae. Tomato flowers lack nectaries, so bumble bees in greenhouses are typically fed artificial nectar in their colony boxes.

Bombus terrestris is the species of choice for most of the bumble bee rearing industry because it is readily available in Europe, where the technology for year-round production and commercial rearing techniques evolved. It is easily reared, can produce large colonies, and effectively "buzz pollinates" tomatoes under greenhouse conditions. Successful rearing and use of other species of bumble bees in their native areas in North America have shown that alternatives are possible within the world distribution range of bumble bees (Thorp 2003). Alternatives are being explored in Japan (Ono 1997) and more recently in Mexico (C. Vergara, pers. comm.)

THE ECONOMICS OF BUMBLE BEES USED FOR GREENHOUSE PRODUCTION

Worldwide Production

Despite the fact that rearing practices have been tested on many of the 250 species of bumble bee, only five species (four belonging to the subgenus *Bombus*) are currently used as commercially produced pollinators worldwide (Velthuis and van Doorn 2006). Although bumble bees are efficient pollinators of a variety of crops, including red clover, cranberries, blueberries, kiwifruit, almonds, apples, and pears (Loken 1958, Holm 1966b, Corbet et al. 1988, Cane and Payne 1993, MacKenzie and Averill 1995, Goodell and Thomson 1997, Macfarlane and Patten 1997, Mayer and Lunden 1997, Stubbs and Drummond 2001, Thorp 2003), approximately 95% of commercially-reared colonies are used in production of greenhouse tomatoes (*Lycopersicon esculentum*) (Velthuis and van Doorn 2006, van Doorn, unpubl.) and sweet peppers (*Capsicum annuum*) (Shipp et al. 1994, Ercan and Onus 2003). The benefits to growers include reduced costs from not having to pollinate mechanically using shaker tables or by hand with electronic vibrating wands, ease in monitoring bumble bee activity, increased fruit yields, little or no need for pesticides, and improved fruit quality leading to higher sales prices (Velthuis and van Doorn 2006).

De Jonge first uncovered the economic benefits of using bumble bees for pollination of greenhouse tomatoes in 1985, and subsequently founded the commercial bee rearing company Biobest in 1987 (Velthuis and van Doorn 2006). Koppert Biological Systems and Bunting Brinkman Bees (BBB) initiated rearing production in the next two years. Even with the present availability of over thirty other producers worldwide, the initial three still dominate the market share (Velthuis and van Doorn 2006). Almost one million colonies of primarily *Bombus terrestris* and *B. impatiens* are reared annually in commercial facilities and are distributed throughout the world (Velthuis and van Doorn 2006). Colonies of *B. terrestris* shipped to Japan from Europe increased from 5,000 in 1992 to 40,000 in 1999 (Ono 1997, Thorp 2003), and Russia imported more than 6,500 colonies of *B. terrestris* between 1994 and 1996 (Berezin and Beiko 1996). In 2004, 99,000 acres of greenhouse tomato production were pollinated worldwide by bumble bees, with an estimated value of approximately $15 billion (Velthuis and van Doorn 2006).

North America

In 2003, total North American greenhouse tomato production was estimated at 528,078 metric tons (Calvin and Cook 2005). Canada was the largest producer with 42% of total production, followed by the United States at 30%, and Mexico at 25% (Calvin and Cook 2005). In the United States alone, cultivation of fresh market tomatoes generates approximately $1.3 billion in revenues (USDA-NASS 2005), with 37% of all tomatoes sold grown in greenhouses (Calvin and Cook 2005).

The primary species of bumble bee originally raised in North America included an eastern species, *Bombus* (*Pyrobombus*) *impatiens*, and a western species, *Bombus* (*Bombus*) *occidentalis*. In 1998, after commercial *B. occidentalis* populations were decimated by disease, the United States Department of Agriculture Animal and Plant Health Inspection Service (APHIS) allowed transportation of eastern *B. impatiens* to the western United States in response to the demand for pollination services by growers (Flanders et al. 2003). *B. impatiens* is now the only commercially significant species in North America. In Canada, *B. impatiens* was first allowed into the Fraser Valley of British Columbia in late 1999, but at least four queens have been reported as escaped into the wild (K. MacKenzie, pers. comm.).

Bombus terrestris was allowed into Mexico in 1995 and 1996 without the knowledge of the U.S. or Canadian regulatory agencies (Flanders et al. 2003). Shortly thereafter, the microsporidian *Nosema bombi*, an internal parasite of bumble bees, was identified in shipments of *B. terrestris* in Mexico, prompting the destruction of the colonies intended for Jalisco, Mexico, and a retraction of import permits (Golobuv, pers. comm.). Use of *B. terrestris* for greenhouse production in Mexico has since been replaced by *B. impatiens*, with up to 55,000 colonies sold per year (Velthuis and van Doorn 2006) since importation by Koppert de Mexico in 2001 (Martinez Guzman 2005). In 2004, bumble bee colonies were imported through Mexico City by three major supplier/distributors: Agroinvernadero de Mexico (118 colonies), Distribuciones Imex (5549 colonies), and

Koppert de Mexico (6680 colonies) (Vergara pers. comm.). However, inspection methods and protocols remain inadequate to properly screen incoming shipments for diseases and parasites that may be carried by colonies of imported *Bombus*.

The economic significance of this industry cannot be ignored. However, the environmental costs of bee importation should be quantified and understood. The North American continent hosts over 4,000 species of native bees, including fifty-four species of native *Bombus*, some of which could be further investigated and possibly reared as commercial pollinators of agricultural crops. The lack of regulations that would require the use of native species has discouraged research on these alternatives, which creates a risk of having no native species commercially available if the supply of *B. impatiens* is diminished. It is quite likely that cost-effective alternatives using indigenous species of *Bombus* could be developed through pragmatically applied research, as discussed in the Recommendations section, starting on page 21.

NEGATIVE ECOLOGICAL CONSEQUENCES OF IMPORTING NON-NATIVE *BOMBUS* SPECIES

Diseases and Parasites

North American honey bee colonies have experienced drastic declines in the last ten years due to the introduction of parasitic mites such as the *Varroa* (*V. destructor = jacobsoni*) and tracheal mites (*Acarapis woodi*). Bumble bees face similar threats, hosting the microsporidian *Nosema bombi*, the microorganism *Crithidia bombi,* the tracheal mite *Locustacarus* (= *Bombacarus*) *buchneri* (Skou et al. 1963, MacFarlane et al. 1995, van den Eijnde 2000, Otterstatter et al. 2005, van der Steen 2000, Velthuis & van Doorn 2006), and hymenopteran brood parasitoids such as *Melittobia acasta* and *M. chalybii* (MacFarlane & Donovan 1989, de Wael et al. 1993, Whitfield & Cameron 1993, Velthuis & van Doorn 2006). Bumble bees are hosts to a large number of parasites, and for most, very little or nothing is known about their effects, epidemiology, or evolutionary ecology (Schmid-Hempel 2001). Microorganisms such as *Nosema, Apicystis*, and *Crithidia* and other internal parasites such as *L. buchneri* can be difficult to detect when inspecting commercial colonies (Thorp 2003). Methods and standards for detection of parasites affecting imported bees must be improved. This is especially relevant to *Bombus* colonies, because once they become infected, they are constrained from becoming resistant to a particular parasite since all workers descend from the same mother queen and her mates, maintaining the same genetic environment (Schmid-Hempel 2001).

Commercially-reared bumble bees can escape from greenhouses in relatively large proportions (Morandin et al. 2001) if growers are not cautious in preventing their accidental release. Infected bumble bees can readily transmit intestinal parasites between individuals (Durrer and Schmid-Hempel 1994). Disease transmission between commercial and wild populations of bumble bees has been demonstrated in field studies (Colla et al. 2006) and is of grave concern. Particularly disquieting are reports that at least five species of North American bumble bees have disappeared from much of their native range since the late 1990s. In 1992 to 1994 (Flanders et al. 2003), bumble bees were shipped from North America to European rearing facilities; raised alongside

B. terrestris, where they could have become infected with diseases and parasites; and the colonies were then shipped back to North America and released. Since that time, severe declines have been observed in three widespread North American species, *B. occidentalis*, *B. affinis*, and *B. terricola*, and in *B.* (*Psithyrus*) *ashtoni*, a specialized social parasite of *B. affinis* and *B. terricola*. All of these species except the parasitic one are in subgenus *Bombus*, the same subgenus as *B. terrestris*. *B. franklini*, another member of subgenus *Bombus*, has suffered a precipitous decline in its native range of southern Oregon to northern California since 1998 and may now be extinct, as it has not been observed in the wild since before 2004 (Thorp 2005). An additional species in this subgenus, *B. lucorum*, and the western parasitic species *B. suckleyi* have not been investigated but may also be at risk. These seven species represent 13% of the North American bumble bee fauna.

The causes of these abrupt, severe, and widespread declines are not well understood due in part to lack of extant populations in most accessible areas. Focused surveys and population assessments of rare native bees are critically needed. The population crashes of species in the subgenus *Bombus* may be the result of infestations of *Nosema* and possibly other parasites that could have been introduced by bumble bees imported in the early-1990s (Buchmann and Ascher 2005, Velthuis and van Doorn 2006, Whittington and Winston 2004, Colla et al. 2006, Javorek unpubl. data). The declines in wild bees described above occurred soon after devastating *Nosema* outbreaks were reported in commercial colonies. *Nosema bombi* has been shown in laboratory experiments to increase mortality rates in infected colonies up to five times those of uninfected colonies of *B. terrestris*, and to prompt physical abnormalities such as deformed wings and distended abdomens in infected bumble bees (Ott and Schmid-Hempel 2004). A study of pathogen spillover from commercial bumble bees to wild populations in Canada demonstrated that *Nosema bombi* was three times more prevalent among bumble bees foraging near greenhouses than it was in areas without them (Colla et al. 2006).

The same study reports up to 26% infestation of the intestinal pathogen *Crithidia bombi* for wild bumble bees captured foraging near commercial greenhouses in Canada, although it was absent in those caught elsewhere (Colla et al. 2006). Similarly, transmission rates of *C. bombi* via flower visits were reported at 20-40%, with higher likelihood of bees becoming infected by visiting simple versus complex inflorescences (Durrer and Schmid-Hempel 1994, Schmid-Hempel 2001). The pathogen has been shown to alter foraging behavior in host bees (Otterstatter et al. 2005) by reducing their cognitive ability to identify and manipulate nectar flowers, causing highly infected bees to spend as much as 200% more time on visits to complex flowers in order to manipulate them properly for nectar and pollen resources (Gegear et al. 2006, Gegear et al. 2005). By altering the flower-visiting behavior of workers, *C. bombi* might have far-reaching but unpredictable effects on plant communities that depend on bumble bees for reproduction. Additionally, the increased energetic expense can reduce the fitness of entire colonies (Yourth and Schmid-Hempel 2004). A co-adaptive relationship also exists between strains of *C. bombi* and its local *Bombus* hosts, wherein *C. bombi* introduced from distant areas has been shown to cause higher levels of mortality than infections with local strains (Imhoof and Schmid-Hempel 1998). It is particularly notable that in studies observing the effects of *C. bombi*, the colonies used in these investigations arrived from commercial suppliers already infected with the microorganism (Gegear et al. 2006, Gegear et al. 2005, Otterstatter et al. 2005). Because *C. bombi* had not been detected in wild populations of North American *Bombus* before the Colla et al. (2006) study, it is suspected to be a European parasite recently introduced by commercial greenhouses to North America, increasing its potential danger to native bees.

In many places, bumble bees and other pollinators have declined as a result of habitat destruction (Williams 1986) and the use of modern broad-spectrum insecticides (Kevan 1999; Kearns et al. 1998). However, these factors are unlikely to be the primary causes of the North American declines seen in subgenus *Bombus*, because in the same locations and habitats where subgenus *Bombus* declined, most other bumble bee species and subgenera remain numerous (Giles and Ascher 2006; Jean 2006; Reed 1995, C. Reed unpubl. data; Reed and Silbernagel 2006; Colla and Packer, in prep.; D. Reimer, pers. comm.; J. Ascher, R. Jacobson, T. Roulston, R. Thorp, and D. Wagner, unpubl. data), and because the sudden disappearance of subgenus *Bombus* across a large geographic area, beginning in the 1990s, did not correspond with any known or perceived changes in pesticide use or habitat degradation.

Problems with diseases and parasites have been exacerbated by the practice of shipping bumble bees to rearing facilities in states or countries far from their native range, where they may become infected, then returning them to their place of origin for use in commercial facilities. Although many of the symptoms resulting from parasite infections are sub-lethal, studies have only been performed only on commercially-produced species under artificial conditions (e.g., constant food supply). The effects of these parasites on other species under variable environmental conditions remain unknown but they could potentially cause significant mortality. Given the insufficient regulations in place to prohibit the introduction of diseases and parasites, and the inherent difficulties involved in testing imported bumble bees for pathogens, future importations of non-native bumble bees -- including exported and reintroduced native bees -- should be considered with extreme caution.

Weakening the Genetic Integrity of Native Populations

Most of the ten subspecies of *Bombus terrestris* have been utilized in areas outside of their natural ranges (Velthuis and van Doorn 2006). Subspecies of *Bombus* collected from various locations have been shown to interbreed (Ornosa 1995, de Jonghe 1986, Duchateau 1996, van den Eijnde and de Ruijter 2000, van Doorn unpubl.). Commercial *B. terrestris* from Europe were observed mating with the species *B. hypocrita* from Japan (Goka 2000, Dafni et al. 2001), which, if successful in the wild, could dilute the genetics of native pollinator populations. In parts of North America where *Bombus* is the most important pollinator, genetic mixing between commercial bumble bees and native species would have the potential to threaten co-evolved plant-pollinator relationships and habitats, as has been inferred in cases reported from Japan (Matsumura et al. 2004, Dafni et al. 2001, Goka 2000, Ono 1997). Similarly, *B. impatiens* is biologically similar to at least two of Mexico's twenty-four species of native bumble bees, *B. ephippiatus* and *B. wilmattae*, which makes interbreeding a real possibility (C. Vergara, pers. comm.).

Establishment in Non-Native Ecosystems

Greenhouse bumble bee colonies populations collectively can reach over 20,000 individuals (Colla et al. 2006), quantities that would be difficult to contain fully. Up to 73% of greenhouse bumble bees have been reported to forage outside the greenhouse enclosures where their colonies are housed, in order to visit plants located nearby (Morandin et al. 2001). This activity may put them in direct or indirect contact with native bumble bees visiting the same flowers. In Mexico, most greenhouses are of an Israeli design that opens to the sides, which allows bees to exit easily into the wild. Queens of B*. impatiens* have been found in the wild in Jalisco, Mexico, indicating that this species has not only escaped from greenhouse containments, but it is becoming naturalized in a non-native environment (Vergara, pers. comm.), which could have significant impacts on local bee fauna.

Examples of *Bombus terrestris* and other species of bumble bee readily establishing themselves in new environments include: *Bombus hortorum, B. ruderatus, B. subterraneus*, and *B. terrestris* from the United Kingdom to New Zealand from 1885-1906; *B. t. audax* in the state of Tasmania, Australia since 1992 (possibly arriving from New Zealand); *B. impatiens* from Canada and the U.S. to Mexico; *B. ruderatus* from New Zealand to Chile and Argentina; and *B. terrestris* in Israel, Japan, and Chile since the 1960s (Velthuis and van Doorn 2006, Matsumura et al. 2004, Goulson 2003, Hingston et al. 2002, Morales and Aizen 2002, Ruz 2002, Stout and Goulson 2000, Buttermore 1997, Dafni and Schmida 1996, Roig Alsina and Aizen 1996, Macfarlane and Gurr 1995, Arretz and MacFarlane 1986, Hopkins 1914). In countries such as Tasmania, where it has been introduced and conditions are similar to its native environment, *B. terrestris* has demonstrated a rapid rate of range expansion up to 90 kilometers per year (Hopkins 1914). It maintains higher population densities than semi-social and solitary bees across a broad range of habitats and geographical regions, and is a generalist forager (Goulson 2003), allowing *B. terrestris* populations to potentially occupy a wide diversity of niches also used by different species of pollinator.

Competition

Competition is an issue for co-occurring species of native and introduced bumble bees and should be considered when assessing the risks of importations into new ranges, especially in areas where native populations are already limited by habitat fragmentation and other negative impacts. In Japan, queens of *Bombus terrestris* have been shown to kill queens of *B. ignitus* in close proximity (Ono 1997) and will use nest sites similar to those selected by native species such as *B. hypocrita sapporoensis* and *B. diversus tersatus* (Matsumura et al. 2004, Velthuis and van Doorn 2006). Smaller native bees have also been deterred from foraging by the presence of bumble bees (Hingston and McQuillan 1999). In Tasmania, introduction of *B. terrestris* has caused a demonstrable reduction in foraging by two native species of non-bumble bees, *Chalicodoma* (Hingston and McQuillan 1999).

Some bumble bees with short probosces, including *Bombus terrestris, B. affinis, B. terricola,* and *B. occidentalis*, bite holes at the base of flowers with long corollas to extract nectar (Inouye 1983, Laverty and Harder 1988, Thorp 2003), often without effecting pollination (Goulson 2003). This "nectar robbing" behavior allows *B. terrestris* and other short-tongued bees to compete directly with long-tongued bees. This competition may then decrease pollination rates for native plants with long corollas by reducing their nectar rewards available to attract other, more effective pollinators (Maloof and Inouye 2000).

Interspecies competition may be occurring in Canada. Surveys of Canadian native bees from 1991-2005 have shown a dramatic decline of the previously abundant bumble bee, *Bombus terricola*, while during the same period, the once infrequently encountered *B. impatiens* has become the most abundant bumble bee species in New Brunswick and mainland Nova Scotia (Javorek unpub. data). The recent expansion of *B. impatiens* may be partly due to the use of this bee as a pollinator of greenhouse crops and lowbush blueberry (Javorek pers. comm.), although this could also be due to climatic warming and/or changes in land use.

As with any exotic species, there are concerns about the effects of *Bombus terrestris* releases on native populations of bumble bees in terms of habitat and resource use. Population declines in closely-related species of the subgenus *Bombus* throughout their North American habitats have been reported recently (Buchmann and Ascher 2005, Thorp 2005). These declines may open up an ecological niche for introduced species in otherwise relatively stable and fully utilized habitats. *B. terrestris* is able to naturalize readily in new environments, even with low numbers of founding queens (Buttermore et al. 1998), which could cause competition with native *Bombus* populations that have suffered declines and may be attempting to reestablish in their native habitats and could interfere with conservation efforts to restore these native populations.

After the recent and dramatic decline of North American bumble bees in the subgenus *Bombus*, this subgenus in particular may be very vulnerable to competition. *B. occidentalis*, *B. terricola*, and *B. affinis* were once common and geographically widespread. Today, it appears that the only known stable remaining population of *B. occidentalis* is in the Rocky Mountains; of *B. terricola* is in Algonquin Park, Canada; and none have been reported for *B. affinis*. In all other areas of study throughout North America, these species of subgenus *Bombus* appear to be at grave risk of extinction, if not already lost. For example, the extensive decline of *Bombus affinis* has been documented in a long-term study of bumble bee diversity in Guelph, Ontario, and by extensive sampling throughout its native range (Colla and Packer, in prep.). These struggling species of the subgenus *Bombus* are unlikely to respond positively to the introduction of a very closely related (consubgeneric) generalist competitor, such as *B. terrestris*. Since many North American early spring and late fall flowering plants may rely on native *Bombus* populations for pollination in colder regions, the loss of these species may result in substantial changes in the availability of seeds and berries for native birds and mammals, potentially producing a cascading impact on North American biodiversity.

CURRENT REGULATORY RESTRICTIONS

Other Continents

The actual or potential risks caused by commercial *Bombus* colonies to wild populations have prompted several governments to impose restrictions on the importation of some subspecies of *B. terrestris,* such as *B.t. canariensis* in the Canary Islands and *B.t. terrestris* in Norway (Velthuis and van Doorn 2006). The Japanese government has included *B. terrestris* in its Invasive Alien Species Act (Velthuis and van Doorn 2006), and future importation will likely be highly restricted or banned. China and South Africa do not allow *B. terrestris* to be imported at all (Velthuis and van Doorn 2006), although some existing populations are being reared in-country. In New South Wales, the alteration of natural pollination dynamics caused by the presence of *B. terrestris* in other countries has prompted its listing as a "Key Threatening Process," and in Victoria, Australia, it is listed as a "Potentially Threatening Process."

North America

Almost all laws and regulations affecting the importation of bees focus on preventing diseases and parasites associated with plants and honey bees, without considering the potentially adverse environmental impacts associated with the bees themselves (Flanders et al. 2003). Bumble bee rearing facilities are inspected by national and state veterinary services, but often the importing countries are only prepared to identify diseases and pests affecting honey bees, and regulatory agency personnel may be insufficiently trained or understaffed to handle proper inspection procedures (Velthuis and van Doorn 2006, Velthuis, pers. comm.). Internal parasites affecting bumble bees can be quite difficult to detect, particularly at low levels of infection when colonies may otherwise appear healthy. There are no current international standards for inspection that would prevent the further spread of diseases and parasites.

United States

The U.S. Honey Bee Act of 1922 allows the Secretary of Agriculture, via responsibilities delegated to the Animal and Plant Health Inspection Service (APHIS), to prohibit or restrict the importation of honey bees into the U.S. in order to prevent the introduction of diseases and parasites, but it does not regulate the importation of other pollinators (Flanders et al. 2003). Instead, non-*Apis* pollinators, such as *Bombus* species, are regulated under the Plant Protection Act of 2000 (PPA), again, with a focus on preventing the introduction of parasites and pathogens that could adversely affect their beneficial pollination of plants. The 2004 amended regulations allow the importation of queen and packaged honey bees only from Australia, Canada, and New Zealand. Certain bees other than honey bees can be imported into the U.S. from Canada, including two species of bumble bee, *Bombus impatiens* and *Bombus occidentalis*; as well as the Alfalfa leafcutter bee (*Megachile rotundata*), Blue orchard bee (*Osmia lignaria*), and Horn-faced bee (*Osmia cornifrons*) (Federal Register 2004). Other species may only be imported through permits issued by the USDA to federal, state, or university researchers for experimental purposes (Federal Register 2004). Bumble bees such as *B. impatiens* are currently shipped anywhere within the contiguous 48 states with no federal restrictions.

Canada

The Canadian Food Inspection Agency (CFIA) is responsible for regulating bees under the 1990 Health of Animals Act, with importations regulated under the Honey Bee Prohibition Regulations of 2004. These regulations are reviewed every two years for possible effects of introduced diseases on the Canadian beekeeping industry. Similar to the U.S. PPA, the Health of Animals Act of 1990 covers other pollinating species by administration from the Plant Products Directorate, Plant Health Division, Export/Import Section. While importation and exportation is regulated by the CFIA, movement of bees within Canada is regulated by individual provinces.

Mexico

The Federal Law of Animal Health (*Ley Federal de Sanidad Animal*) of 1993 established monitoring, prevention, control, and eradication of diseases for all terrestrial animals in Mexico (*Ley Federal de Sanidad Animal* 2004). Under the Law, the Secretary of Agriculture, Livestock, Rural Development, Fishing, and Food (*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación*, SAGARPA) created the National Service for Agro-Food Health, Safety, and Quality (*Servicio Nacional de Sanidad,* *Inocuidad y Calidad Agroalimentaria*, SENASICA) to regulate the importation of agricultural products into Mexico, including requirements for three species of bumble bee: *B. impatiens*, *B. occidentalis*, and *B. ephippiatus*. The restrictions require that official health certificates stating that the imported bumble bees are free of infections from *Nosema*, *Varroa*, and fungal diseases accompany each shipment into Mexico (SENASICA 2006). Incoming colonies are then sent to the Animal Health Experimental Service Center (*Centro de Servicios de Constatación en Salud Animal*) for examination for ectoparasites and *Nosema* infection, with documentation complying with the requirements of Article 24 of the Federal Law (SENASICA 2006).

Tri-national Policies

The Progress Report on the National Invasive Species Management Plan (updated July 2005) indicates that a North American strategy will be developed to address invasive species based upon existing tripartite agreements between the U.S., Canada, and Mexico (Action item #38) (NISC 2005). The report also indicates that the National Invasive Species Council will enhance international research collaborations to address efforts in managing invasive species (Action item #39) (NISC 2005), which highlights the importance of addressing the issue of *B. terrestris* importation to North America through expert tri-national collaborations such as the North American Pollinator Protection Campaign (NAPPC).

RECOMMENDATIONS: ISSUES NEEDING IMMEDIATE ACTION

It is vitally important to focus on the issues that have caused problems in populations of native and managed pollinators and to address the ecological factors at play before seeking the introduction of non-native species. Non-native species introductions may have dramatic negative consequences. In the last century, invasive species of all types have cost the U.S. an estimated $137 billion in damages (Pimentel et al. 2000). Yet introductions of exotic plants and animals persist, partly because those who introduce exotic plants and animals may not fully understand or bear the consequences of their behavior (Perrings et al. 2002), which can be devastating on both economic and ecological scales. It is imperative to promote the commercial use of native bumble bees within their countries of origin, rather than import exotic species, such as *Bombus terrestris,* with the potential for damaging consequences.

The process of developing economically feasible supplies of native pollinators for greenhouse tomatoes needs to be accelerated. Only one native North American bumble bee species is currently used in widespread commercial production. Should any problems occur with its supply, as they did with *Bombus occidentalis*, growers would have no native pollinators to use as an alternative. Researchers are investigating the use of native pollinators instead of non-natives for greenhouse tomato production, and more work is needed to quicken the process of designating alternative species that are both ecologically and economically viable. Japanese scientists have already succeeded in rearing native *B. ignitus* for commercial use. In Mexico, the widely distributed native *B. ephippiatus* has been successfully reared in the laboratory and could be further studied for commercial production to replace imports of *B. impatiens*, which is a non-native species. Also in Mexico, native stingless bees (*Nannotrigona perilampoides*) have been studied for their pollination efficiency on greenhouse tomatoes (Cauich et al. 2004). Australian scientists have researched solitary carpenter bees as alternatives to introduced bumble bees (Hogendoorn et al. 2000), and are currently investigating the use of the blue banded bee, *Amegilla* sp., a buzz pollinator. The results of similar studies could provide invaluable information for the use of native bumble bees in North America, and studies will begin soon for *Bombus* at the USDA Logan Bee Lab in Utah.

Because economic considerations are driving the market for the use of non-native bumble bee species, government regulatory agencies should take ecological considerations into acount in decisions involving the importation of potentially invasive species. Specific testing protocols would need to be developed in order to provide full consideration of the ecological effects of non-native pollinators. What may be a short-term solution for a small constituency of growers and bee suppliers could cause the collapse of both native ecosystems and economic interests by decimating natural pollinator populations and introducing deleterious diseases. Policymakers should review the experiences of other countries when assessing the impacts of the importation of non-native pollinators to North America.

Recommendations:

Recommendations #1-4 support existing legislation, treaties, and agreements; advocate additions to existing frameworks; or call for more resources to be earmarked for pollinator research.

1) Continue to prohibit the importation of *Bombus terrestris* into Canada, Mexico, and the United States.

2) Fund research to promote economically viable commercial rearing and use of pollinators native to the Canada, Mexico, and the USA, both within those countries and within each pollinator's natural distribution range.

3) Continue to prohibit the importation of bees to North America from other continents, especially importation of additional non-native species. Any legislation should exempt the Western Honey Bee (*Apis mellifera*), as this species has a unique regulatory status, but should apply to all other bee species, including other honey bee species (e.g., *Apis cerana*).

4) Prohibit species of bees native to North America from being exported to commercial rearing facilities overseas and later returned to North America.

Recommendations #5-8 concern concepts that do not currently have an institutional framework to implement them. The authors advise agencies to carefully consider these recommendations and create implementation strategies that will ensure healthy pollination industries and sustainable ecosystems.

5) Use existing international instruments, such as the North American Free Trade Agreement (NAFTA), to address issues regarding the importation, quarantine, and monitoring of bees, including international standards of inspection. Train customs personnel and port agricultural inspection officers regarding bumble bee regulations in order to create uniform enforcement of existing laws and to prevent illegal importation.

6) Evaluate current importation practices to ensure that environmental laws are not being violated by the present commercial movement of *Bombus* species, and to create opportunities for tri-national agency cooperation.

7) Study and monitor species at risk, with special focus on *Bombus franklini* and *B. affinis*, which might be harmed by the importation of potential competitors and disease reservoirs such as *B. terrestris* and commercial *B. impatiens*. Consider potential economic and ecological costs when calculating the long-term effects of releasing non-native pollinators.

8) Consider restricting the transport of non-*Apis* bee species within North America (both between the USA, Canada, and Mexico, and between biologically distinct regions within each country) to areas beyond their existing ranges, to prevent establishment and spread of invasive bee populations and of associated exotic parasites and diseases. Any potential restrictions should specifically exempt honey bees (*Apis mellifera*) and certain non-*Apis* species already long-established and generally distributed in North America, such as the Alfalfa Leafcutting Bee, *Megachile rotundata*, but should include economically important species with restricted ranges such as *Bombus impatiens*.

The partners of the North American Pollinator Protection Campaign (NAPPC) represent a collaboration of more than one hundred agencies, government and non-government institutions, garden and grower groups, scientists, and other stakeholders involved in pollinator conservation in Canada, Mexico, and the United States; and are poised to offer expert guidance in effectively implementing the recommendations proposed in this white paper.

The opinions and recommendations expressed in this paper represent a consensus of the authors as members of a NAPPC Task Force, and may not necessarily reflect the views of all NAPPC partners, partner institutions, or other affiliates.

NAPPC urges industry, growers, governments, scientists and non-government organizations to work together to recognize their stake in sustainable practices. Applied research, active monitoring, documentation, and remediation can go a long way to ensure that a healthy environment and a healthy agricultural industry coexist now and in the future.

Please contact NAPPC at www.nappc.org or www.pollinator.org for further information.

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References Cited

Alford, D. V. 1975. Bumblebees. Davis-Poynter, London.

Arretz, P. V. and R. P. MacFarlane. 1986. The introduction of *Bombus ruderatus* to Chile for red clover pollination. Bee World 67: 15-22.

Berezin, M. V. and V. B. Beiko. 1996. Bumblebee keeping in Russia – new problems and prospects. P. 121 *In* Programme Abstracts, 4th International Colloquium Social Insects. August 18-24, 1996. Russian Basic Research Foundation. Saint Petersburg, Russia.

Buchmann, S. L. 1983. Buzz pollination in angiosperms. Pp. 73-113 *In* C. E. Jones and R. J. Little (Eds.), Handbook of experimental pollination biology. Van Nostrand-Rheinhold, New York.

Buchmann, S. and J. S. Ascher. 2005. The plight of pollinating bees. Bee World September: 71-74.

Buttermore, R. E. 1997. Observations of successful *Bombus terrestris* (L.) (Hymenoptera: Apidae) colonies in Southern Tasmania. Australian Journal of Entomology 36: 251-254.

Buttermore, R. E., N. Pomeroy, W. Hobson, T. Semmens, and R. Hart. 1998. Assessment of the genetic base of Tasmanian bumble bees (*Bombus terrestris*) for development as pollination agents. Journal of Apicultural Research 37: 23-25.

Calvin, L. and R. Cook. 2005. North American greenhouse tomatoes emerge as a major market force. USDA Economic Research Service, Amber Waves 1(3): 20-27.

Cane, J. H. and J. A. Payne. 1993. Regional, annual, and seasonal variation in pollinator guilds: intrinsic traits of bees (Hymenoptera: Apoidea) underlie their patterns of abundance at *Vaccinium ashei* (Ericaceae). Annals of the Entomological Society of America 86(5): 577-588.

Cauich, O. J., J. G. Quezada-Euán, J. O. Macias-Macias, V. Reyes-Oregel, S. Medina-Peralta, and V. Parra-Tabla. 2004. Behavior and pollen efficency of *Nannotrigona perilampoides* (Hymenoptera: Meliponini) on greenhouse tomatoes (*Lycopersicon esculentum*) in subtropical Mexico. Journal of Economic Entomology 97: 475-481.

Colla, S. and L. Packer. In prep. Evidence for the widespread decline of a North American bumble bee (*B.affinis*).

Colla, S. and L. Packer. In prep. Bumble bee species diversity decline in Southern Ontario, Canada.

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

Corbet, S. A., H. Chapman, and N. M. Saville. 1988. Vibratory pollen collection and flower form: bumble-bees on *Actinidia, Symphytum, Borago*, and *Polygonatum*. Functional Ecology 2: 147-155.

Dafni, A. and A. Schmida. 1996. The possible ecological implications of the invasion of *Bombus terrestris* (L.) (Apidae) at Mt. Carmel, Israel. Pp. 183-200 *In* A. Matheson, S.L. Buchmann, C. O'Toole, P. Westrich, and I.H. Williams (Eds.), The conservation of bees. Academic Press, London.

Dafni, A., P. Kevan, V. Fonseca, and C. Gross. 2001. *Bombus terrestris* pest or pollinator? An assessment of its wide introduction for commercial purposes. Unpublished report presented to the F.O.A.

Duchateau, M. J. 1996. Is kin conflict expressed in the colony cycle of the bumble bee *Bombus terrestris*? P. 404 *In* Proceedings of the XX International Congress of Entomology. Firenze, Italy.

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

van den Eijnde, J. van den. 2000. Bumble bee parasites: *Nosema bombi* and *Locustacarus buchneri*. Pp. 39-47 *In* Insect Pollination in Greenhouses. M. J. Sommeijer and A. Ruijter, (Eds.). Utrecht University & Ambrosiushoeve. Utrecht, Hilvarenbeek.

van den Eijnde, J. van den and A. de Ruijter. 2000. Bumble bees from the Canary Islands: mating experiments with *Bombus terrestris* L. from Netherlands. Proceedings of the Section on Experimental and Applied Entomology of the Netherlands Entomological Society 11: 159-162.

Ercan, N. and A. N. Onus. 2003. The effects of bumblebees (*Bombus terrestris* L.) on fruit quality and yield of pepper (*Capsicum annuum* L.) grown in an unheated greenhouse. Israel Journal of Plant Sciences 51: 275-283.

Federal Register. 2004. U.S. Department of Agriculture, Animal and Plant Health Inspection Service Docket No. 98-109-2, 69 (203): 61735-61755. Internet access: http://a257.g.akamaitech.net/7/257/2422/06jun20041800/edocket.access.gpo.gov/2004/04-23416.htm.

Flanders, R. V., W. F. Wehling, 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?

Proceedings of Thomas Say Publications in Entomology. Entomological Society of America. Lanham, MD.

Free, J. B. and C. G. Butler. 1959. Bumblebees. Collins Publishing, London.

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

Gegear, R. J., M. C. Otterstatter, and J. D. Thomson. 2005. Does parasitic infection impair the ability of bumble bees to learn flower-handling techniques? Animal Behaviour 70(1): 209-215.

Giles, V. and Ascher, J. S. 2006 (In prep.). A survey of the bees of the Black Rock Forest Preserve, New York. (Hymenoptera: Apoidea).

Goka, K. 2000. Influences of invasive European bumble bees on Japanese native species: Genetic disturbance and parasitic invasion. National Institute for Environmental Studies, Global Environment Division. Tsukuba, Japan. Internet website: http://www003.upp.so-net.ne.jp/consecol/english/goka_report/goka_report.html.

Goodell, K. and J. D. Thomson. 1997. Comparisons of pollen removal and deposition by honey bees and bumble bees visiting apple. Acta Horticultura 437: 103-107.

Goulson, D. 2003. Effects of introduced bees on native ecosystems. Annual Review of Ecology, Evolution, and Evolutionary Systematics 34: 1-26.

Heinrich, B. 1979. Bumblebee Economics. Harvard University Press. Cambridge, Massachusetts.

Hingston, A. B. and P. B. McQuillan. 1999. Displacement of Tasmanian native megachilid bees by the recently introduced bumble bee *Bombus terrestris* (Linnaeus, 1758) (Hymenoptera: Apidae). Australian Journal of Ecology 47: 59-65.

Hingston, A. B., J. Marsden-Smedley, D. A. Driscoll, S. Corbett, J. Fenton, R. Anderson, C. Plowman, F. Mowling, M. Jenkin, K. Matsui, K. J. Bonham, M. Ilowski, P. B. McQuillan, B. Yaxley, T. Reid, D. Storey, L. Poole, S. A. Mallick, N. Fitzgerald, J. B. Kirkpatrick, J. Febey, A. G. Harwood, K. F. Michaels, M. J. Russell, P. G. Black, L. Emmerson, M. Visoiu, J. Morgan, S. Breen, S. Gates, M. N. Bantich, and J. M. Desmarchelier. 2002. Extent of invasion of Tasmanian native vegetation by the exotic bumblebee *Bombus terrestris* (Apoidea: Apidae). Australian Journal of Ecology 27: 162-172.

Holm, S. N. 1966a. Problems of the domestication of bumble bees. Bee World 47 (Supplement): 179-186.

Holm, S. N. 1966b. The utilization and management of bumble bees for red clover and alfalfa seed production. Annual Review of Entomology 11: 155-182.

Hogendoorn, K., Z. Steen, and M. P. Schwarz. 2000. Native Australian carpenter bees as a potential alternative to introducing bumble bees for tomato pollination in greenhouses. Journal of Apicultural Research 39: 67-74.

Hopkins, I. 1914. History of the humble-bee in New Zealand: its introduction and results. New Zealand Department of Agriculture and Industry Comments 46: 13-29.

Imhoof, B. and P. Schmid-Hempel. 1998. Patterns of local adaptation of a protozoan parasite to its bumblebee host. Oikos 82: 59-65.

Inouye, D. W. 1983. The ecology of nectar robbing. Pp. 152-173 *In* T.S. Elias and B. Bentley (Eds.) The Biology of Nectaries. Columbia University Press, New York.

Jean, R. P. 2006 (In prep.). Species diversity and floral relationships of bees in black oak savannas of northern Indiana. Ph.D. dissertation. Department of Ecology and Organismal Biology, Indiana State University.

Kawakita, A., T. Sota, M. Ito, J. S. Ascher, H. Tanaka, M. Kato, and D. W. Roubik. 2004. Phylogeny, historical biogeography, and character evolution in bumble bees (*Bombus*: Apidae) based on simultaneous analysis of three nuclear gene sequences. Molecular Phylogenetics and Evolution 31: 799-804.

Kearns, C.A., D.W. Inouye, N. M. 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.

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

Ley Federal de Sanidad Animal. 2004. Última Reforma Diario Oficial de la Federación 16-06-2004. Cámara de Diputados del H. Congreso de la Unión, Mexico. 31P.

Loken, A. 1958. Pollination studies in apple orchards of western Norway. Proceedings of the Congress of Entomology 4: 961-965.

MacFarlane, R. P. and B. J. Donovan. 1989. *Melittobia* spp. As parasitoids of bumble and Lucerne leafcutting bees and their control in New Zealand. Proceedings of the 42nd New Zealand Weed and Pest Control Conference Pp. 274-277.

MacFarlane, R. P. and L. Gurr. 1995. Distribution of bumble bees in New Zealand. New Zealand Entomology 18: 29-36.

MacFarlane, R. P. and K. M. Patten. 1997. Food sources in the management of bumble bee populations around cranberry marshes. Acta Horticultura 437: 239-244.

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

MacKenzie, K. E. and A. L. Averill. 1995. Bee (Hymenoptera: Apoidea) diversity and abundance on cranberry in southeastern Massachusetts. Annuals of the Entomological Society of America 88: 334-341.

Maloof, J. E., and D. W. Inouye. 2000. Are nectar robbers cheaters or mutualists? Ecology 81: 2651-2661.

Martinez Guzman, S. J. 2005. Letter to Carlos Vergara from Subdirector of Aeropuertos, SAGARPA. September 26, 2005. Mexico.

Matsumura, C., J. Yokoyama, and I. Washitani. 2004. Invasion status and potential ecological impacts of an invasive alien bumblebee, *Bombus terrestris* L. (Hymenoptera: Apidae) naturalized in Southern Hokkaido, Japan. Global Environmental Research 8: 51-66.

Mayer, D. E. and J. D. Lunden. 1997. A comparison of commercially managed bumblebees and honey bees (Hymenoptera: Apidae) for pollination of pears. Acta Horticultura 437: 283-287.

Morales, C. L. and M. A. Aizen. 2002. Does invasion of exotic plants promote invasion of exotic flower visitors? A case study from the temperate forests of the southern Andes. Biological Invasions 4: 87-100.

Morandin, L. A., T. M. Laverty, P. G. Kevan, S. Khosla, and L. Shipp. 2001. Bumble bee (Hymenoptera: Apidae) activity and loss in commercial tomato greenhouses. Canadian Entomologist 133: 883-893.

National Invasive Species Council (NISC). 2005. Progress report on the meeting the invasive species challenge: National Invasive Species Management Plan. FY 2004. July 22, 2005. Internet website: http://www.invasivespeciesinfo.gov/docs/nisc/progressrpt2005.pdf.

Ono, M. 1997. Ecological implications of introduced *Bombus terrestris*, and significance of domestication of Japanese native bumblebees (*Bombus* spp.). Pp. 244-252 *In* Proceedings, International Workshop Biological Invasions of Ecosystem by Pests and Beneficial Organisms. February 25-27, 1997. National Institute of Agro-Environmental Sciences, Ministry of Agriculture, Forestry, Fisheries. Tsukuba, Japan.

Ornosa, C. 1995. Una nota de atención sobre la introducción artificial de subspecies foraneas de abejorros polinizadores en la Penisula Ibérica (Hymenoptera: Apidae, Bombinae). Boletín de la Asociación Española de Entomología 20: 259-260.

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

Ott, O. and P. Schmid-Hempel. 2004. Pathology and probable life-history effects of *Nosema bombi* (Nosematidae, Microsporidia) in the bumblebee *Bombus terrestris*. P. 91. Proceedings of the First European Conference of Apidology. Udine, Sept. 19-23.

Perrings, C., M. Williamson, E. B. Barbier, D. Delfino, S. Dalmazzone, J. Shogren, P. Simmons, and A. Watkinson. 2002. Biological invasion risks and the public good: an economic perspective. Conservation Biology 6(1): 1. URL: http://www.consecol.org/vol6/iss1/art1.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of non-indigenous species in the United States. BioScience 50: 53-65.

Pouvreau, A. 2004. Les insectes pollinisateurs. Delachaux et Niestle. Lausanne.

Proctor, M., P. Yeo, and A. Lack. 1996. Pp. 387-388 *In* The natural history of pollination. Timber Press Inc. Portland, OR.

Prys-Jones, O. E. and S. A. Corbet. 1991. Bumblebees. Richmond Publishing. Slough, England.

Reed, C. 1995. Insects surveyed on flowers in native and reconstructed prairies (Minnesota). Restoration and Management Notes 13: 210-213.

Reed, C. and J. Silbernagel. (Submitted 2006). Patch assessment and constancy of bumblebees foraging among urban flower patches.

Roig Alsina, A. and M. A. Aizen. 1996. *Bombus ruderatus* Fabricius, un nuevo *Bombus* para la Argentina. (Hymenoptera: Apidae). Physis 5: 49-50.

Ruz, L. 2002. Bee pollinators introduced to Chile: a review. *In* Kevan, P. G. and V. L. Imperatriz-Fonseca (eds.), Pollinating Bees. 2002: The Conservation Link Between Agriculture and Nature. Proceedings Workshop Conservation and Sustainable Use of Pollinators in agriculture, with emphasis on bees. Brasilia Ministry of Environment. Sao Paulo, Brazil. 313 pp.

Schmid-Hempel, P. 2001. On the evolutionary ecology of host-parasite interactions: addressing the question with regard to bumblebees and their parasites. Naturwissenschaften 88: 147-158.

SENASICA (*Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria*). 2006. Online health requirements for importation. Http://senasicaw.senasica.sagarpa.gob.mx/hojaweb/Funcion.aspx. SAGARPA, Mexico.

Shipp, J. L., G. H. Whitfield, and A. P. Papadopoulos. 1994. Effectiveness of the bumble bee, *Bombus impatiens* Cr. (Hymenoptera: Apidae), as pollinator of greenhouse sweet pepper. Scientia Horticulturae 57: 29-39.

Skou, J. P., S. N. Holm, and H. Haas. 1963. Preliminary investigations on diseases in bumble-bees (*Bombus* Latr.). Pp. 27-41 *In* Royal Veterinary and Agricultural College, Copenhagen, Yearbook 1963.

van der Steen, J.. 2000. Diseases and parasites relevant to *Bombus terrestris* L. indoor rearing. Pp. 35-37 *In* Insect Pollination in Greenhouses. M. J. Sommeijer and A. Ruijter, (Eds.). Utrecht University & Ambrosiushoeve. Utrecht, Hilvarenbeek.

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

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

Thorp, R. W. 2005. Species profile: *Bombus franklini*. *In* Shepherd, M. D., D. M. Vaugyan, and S. H. Black (Eds.), Red list of pollinator insects of North America. CD-ROM Version 1 (May 2005). The Xerces Society for Invertebrate Conservation. Portland, OR.

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 Non-native Crops, Whence Pollinators of the Future? Proceedings of Thomas Say Publications in Entomology. Entomological Society of America. Lanham, MD.

United States Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2005. USDA-NASS Agricultural Statistics 2005. Chapter 4: statistics of vegetables and melons. Internet website: http://www.usda.gov/nass/pubs/agr05/05_ch4.PDF.

Velthuis, H. H. W. and A. van Doorn. 2006 (In press). Apidologie. A century of advances in bumble bee domestication and the economic and environmental aspects of its commercialization for pollination.

de Wael, G. M. and O. van Laere. 1993. *Melittobia acasta* and *Bombacarus buchneri*, dangerous parasites in the in vitro rearing of bumble bees. Apiacta 28: 93-101.

Whitfield, J. B. and S. A. Cameron. 1993. Comparative notes on hymenopteran parasitoids in bumble bee and honey bee colonies (Hymenoptera: Apidae) reared adjacently. Entomological News 104: 240-248.

Whittington, R. and M. L. Winston. 2004. Comparison and examination of *Bombus occidentalis* and *Bombus impatiens* (Hymenoptera: Apidae) in tomato greenhouses. Journal of Economic Entomology 97: 1384-1389.

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

Yourth, C. P. and P. Schmid-Hempel. 2004. Virulence and transmission of *Crithidia bombi* in bumble bees. Pp. 83-84 *In* Proceedings of the First European Conference of Apidology. Udine, Sept. 19-23.