Conserving Bumble Bees

Guidelines for Creating and Managing Habitat for America's Declining Pollinators

Rich Hatfield, Sarina Jepsen, Eric Mader, Scott Hoffman Black, and Matthew Shepherd

The Xerces Society for Invertebrate Conservation

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The Xerces Society for Invertebrate Conservation is a nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. Established in 1971, the Society is at the forefront of invertebrate protection, harnessing the knowledge of scientists and the enthusiasm of citizens to implement conservation programs worldwide. The Society uses advocacy, education, and applied research to promote invertebrate conservation.

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Front Cover Photograph
Black-and-gold bumble bee (*Bombus auricomus*) foraging on rattlesnake master (*Eryngium yuccifolium*). Photograph © Steve Hendrix.

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EXECUTIVE SUMMARY

Plant pollination by insects is of paramount importance to both natural and managed landscapes. The nearly fifty species of bumble bees in North America are an essential part of the continent's pollinator communities because they visit a wide array of flowering plants, have a long flight season, and can fly in low light levels and at low temperatures. They are also important on working farms as key pollinators of tomatoes, peppers, blueberries, cranberries, and clover.

Bumble bees need three types of habitat to survive: plants on which to forage for pollen and nectar, nesting sites, and places to overwinter. Relatively recent changes in land usage in the United States have compromised much of this habitat, putting a great deal of pressure on bumble bee populations. A recent survey of North American bumble bees showed that several once-common species are suffering significant range restriction and reduced abundance. The causes of these declines are not fully understood, but the likely factors are loss or fragmentation of habitat, pesticide use, climate change, overgrazing, competition with honey bees, low genetic diversity, and perhaps most significant of all, the introduction of nonnative pathogens.

Regardless of the ultimate cause of bumble bee declines, surviving populations need high quality habitat to persist. Protecting, restoring, enhancing, and creating new bumble bee habitat is the best way to conserve populations of these indispensable animals and hopefully help population trends reverse.

These guidelines outline the significant contribution that bumble bees make to our natural environment and to productive agriculture, and describe the threats they face. They also lay out a set of straightforward strategies to guide the creation and management of good quality bumble bee habitat. By following these practices you can help to slow, stop, or potentially reverse recent population trends and help to maintain bumble bees as a productive part of our environment.

Appropriate management of existing habitat, or thoughtful creation of new foraging patches, can support an abundance of bumble bees—and the essential service of pollination that they provide. (Photograph © Rich Hatfield.)

A loss of habitat and the spread of nonnative disease pose a threat to several species of North American bumble bees. Some species have declined to perilously small populations, and one may already be extinct. Franklin's bumble bee (*Bombus franklini*), shown here, was last seen in the summer of 2006. (Photograph © Dr. Peter Schroeder.)

1 Introduction

Bumble bees are charismatic and easily recognizable pollinators thanks to their large size and distinctive striped patterns, usually of black and yellow, but often with stripes of red, orange, or white. They play an incredibly important role in keeping our environment healthy through pollination of flowers in natural areas and by contributing to successful harvests on farms.

In recent years, much attention has been paid to the importance of pollinators and their contribution to the agricultural economy, in large part because of widespread losses of bees. Declines of pollinator populations are alarming, and the media has paid particular attention to the plight of the introduced European honey bee and Colony Collapse Disorder. Equally important, but less well understood or appreciated, is the parallel decline of native bee populations, particularly bumble bees[1]. A recent study led by Dr. Sydney Cameron, as well as a recent status review by Dr. Robbin Thorp and the Xerces Society, demonstrate that several of North America's nearly fifty species of bumble bees are undergoing dramatic population declines[2–8]. Two species, Franklin's bumble bee (*Bombus franklini*) and the rusty-patched bumble bee (*B. affinis*), may already be on the brink of extinction.

The causes of these declines are not fully understood, but the following are likely playing a role: loss or fragmentation of habitat, pesticide use, climate change, overgrazing, competition with honey bees, low genetic diversity, and perhaps most significant of all, the introduction of nonnative pathogens[1,4,9–11]. Regardless of the ultimate cause of bumble bee declines, protecting existing habitat and creating and maintaining new habitat are some of the most immediate and productive steps that can be taken to conserve these important pollinators. This will require widespread participation and collaboration by landowners, agencies, and scientists. The Xerces Society and others have already begun this effort, but more work is needed. The management practices presented in this document will help to support bumble bee populations, as well as populations of other native pollinators and beneficial insects, and provide a framework to guide you in your management decisions.

1.1 Making the Case for Bees

Based purely on the number of species alone, one can make the case for the conservation of bees to preserve global biodiversity. There are more than 20,000 described species of bees and the number is likely to climb as global collections to survey biodiversity intensify. However, in addition to their pure numbers, bees' contribution to the ecosystem through pollination is perhaps unparalleled, making them keystone species in nearly all terrestrial ecosystems. Because bees actively collect pollen to feed their young, they move pollen from flower to flower. While they do not do this with the intention of cross-pollination, this behavior makes them very effective pollinators. Most other floral visitors are only drinking nectar and therefore the movement of pollen from flower to flower is purely incidental. Bees pollinate over two thirds of the world's agricultural crops (most of the rest, most notably corn, wheat, and rice, are wind pollinated) and are thus directly or indirectly responsible for around one third of the food and beverages that we consume. This contribution to the global economy is measured in hundreds of billions of dollars annually[12–14].

In addition to their role in our agricultural systems, bees also play a significant role in the pollination of plants in wild lands. Around 85 percent of the world's flowering plants are pollinated by animals, the majority

Bumble bees are pollinators of many high-value crops, including peppers, zucchini, eggplant, and tomatoes. (Photograph © iStockphoto/aloha_17.)

by bees. While the pollination of wild plants has less of a direct effect on the global economy, these plants, fruits, and seeds provide food and shelter for a host of animal species, including songbirds and mammals such as grizzly bears[15,16].

Scientists have documented that where populations of pollinators have declined, there is a parallel decline in insect-pollinated plants[17]. This may be particularly true for generalist pollinators like bumble bees[18] and the plants they pollinate. Bees are not only helping to create fruits and seeds for animal consumption, but also helping to maintain biological and genetic diversity in terrestrial ecosystems. Thus, threats to pollinator communities affect not only the pollinators themselves, but the natural ecosystems that surround them and the health of our agricultural systems[15,16,19].

The relative ease with which bumble bees can be identified, combined with their known sensitivity to habitat fragmentation, means that bumble bee communities have the potential to serve as important indicators of ecosystem health and function[17]. With a little practice, anyone can learn to identify most of their local bumblebee species, although there may be a few that are hard to differentiate. For most other bee species, identification to this level of detail is something that requires significant training and specialized equipment (such as a microscope). Because bumble bees are easy to recognize, citizen science monitoring can be a valuable way to collect important data for analysis by trained scientists.

Box 1: Citizen Science Projects

We hope that these guidelines will increase interest in bumble bees and the important role they play in our ecosystem. If you are further interested in bumble bee conservation, please consider participating in the Xerces Society's citizen science projects (www.xerces.org/bumblebees) or joining our mailing list for program updates. We are particularly interested in tracking the status of threatened species and gathering more data on the nesting biology of bumble bees.

Important pollinators in many habitats, bumble bees forage on a wide range of flowers. (Photograph © Rich Hatfield.)

1.2 Bumble Bees as Pollinators

Bumble bees are important pollinators of high-value agricultural crops such as blueberries, cranberries, and clover. They are also the exclusive pollinator of greenhouse tomatoes and peppers, as they have the ability to buzz pollinate, something honey bees cannot accomplish. This makes the community of bumble bees second only to the honey bee as the top insect contributors to the global economy[20].

Their large body size allows bumble bees to be active when temperatures are cool (such as dawn or dusk). Combined with the ability to forage in low light levels, this characteristic makes them significant pollinators in northern latitudes and in high elevation ecosystems[10].

Bumble bees are generalist pollinators, visiting a wide range of plants. Researchers have suggested that generalist pollinators should receive focused conservation attention because of their importance to wild plant populations[18]. This is particularly true for bumble bees, as they are important pollinators in natural areas and agricultural landscapes[20].

1.3 Natural History of Bumble Bees

Bumble bees are social insects that live in colonies like honey bees, although the colonies are much smaller (50–500 members) and their life cycle is different. Honey bee colonies are perennial, with the colony surviving the winter by consuming stored honey reserves and the queen living several years. In contrast, bumble bee colonies are annual, with only the queens living through the winter. These queens emerge from hibernation in the early spring and immediately start foraging for pollen and nectar and begin the search for a nest site. Nests are often located underground in abandoned rodent nests, or above the ground in tufts of grass, old birds' nests, or cavities in dead trees or under rock piles.

After the queen finds a nest site, she constructs a few waxen pots and begins the process of provisioning these with pollen, on which she lays her eggs. Once hatched, the larvae develop into adults in 4–5 weeks, during which time the queen is busy gathering pollen and

incubating the developing larvae. The newly emerged adults become the colony's worker force to gather pollen and nectar. The queen now stays in the nest, where her sole responsibility is to lay eggs and rear offspring.

At some point, depending on the species and habitat conditions, the colony switches from producing workers to rearing the reproductive members of the colony, the new queens and the males (which are called drones). As soon as males reach adulthood they leave the colony in search of a mate, and do not return. New queens remain with the nest until they have mated and the season is over. At that time, the new queens leave the nest in search of an overwintering site. Once she finds her site, she will dig down a few centimeters, usually in soft earth, form an oval cavity, and settle in until the following spring. The remainder of the colony, including the foundress, dies off at the end of the year.

In general, bumble bees forage on a diverse group of plants, though individual species preferences in plants vary due to differences in tongue length. Some species have long tongues and preferentially forage on plants such as penstemon and beebalm that have longer corolla tubes. Species with short tongues forage on flowers with an open structure, such as sunflower and prairie coneflower. In addition, short-tongued bumble bees will engage in "nectar robbing" from flowers with a long corolla tube by biting holes at the base of the corolla and drinking the nectar from the outside of the flower. This practice is called nectar robbing because the bee does not touch the anthers when accessing the nectar, thus taking the reward without contributing to the plant's pollination needs.

Studies of flight distance show that different species of bumble bees vary in how far they forage from the nest[21], with estimates ranging from 275m[22] (900 ft) to 750m[23] (2,460 ft, nearly 1/2 mi.), considerably further than most other native bees. Between species, body size[24] and colony size[20] are good predictors of flight distance. There is also recent evidence that bumble bee foraging distances decrease with nearby high quality foraging habitat[23,25]. This agrees with optimal foraging theory which suggests that bumble bees should be seeking to reduce their flight distances; longer flights require more energy expenditure, and thus increased time foraging for nectar, meaning fewer resources for offspring[26].

Compared to other bees, bumble bees are large in size and covered in dense fur. They also are able to generate heat and regulate their body temperature. This ability to thermoregulate is uncommon among insects and allows bumble bees to fly at colder temperatures than most other bees. Because of this, bumble bees thrive in northern climates and high elevation areas.

Bumble bees can fly half a mile or more to reach foraging patches. (Photograph © Rich Hatfield.)

2 Threats to Bumble Bees in North America

North America's bumble bees vary significantly in the size of their ranges. The species with the smallest range in North America (and possibly the world) is Franklin's bumble bee; its distribution is limited to southwest Oregon and northwest California. In contrast, the brown-belted (*B. griseocollis*) and the golden northern (*B. fervidus*) bumble bees are two species with near cross-continental distribution. Appendix A contains regional guides that will allow you to identify commonly encountered species, as well as some of the imperiled bumble bee species.

Research has documented that at least five species of North American bumble bees—Franklin's and rusty-patched, but also yellow-banded (*B. terricola*), western (*B. occidentalis*), and American (*B. pensylvanicus*)—have experienced severe range reductions. The rusty-patched and Franklin's bumble bees may be on the brink of extinction[4–8,27,28]. In June 2010, the Xerces Society, along with Dr. Robbin Thorp submitted a petition to the U.S. Fish and Wildlife Service to list Franklin's bumble bee as an endangered species under the Endangered Species Act[29]; the bumble bee has not been seen since 2006.

Unfortunately, the most recent data suggests that more than these five species may be suffering significant range declines in the U.S.[30]. While the causes of the declines are not fully understood, likely candidates include habitat fragmentation, overgrazing, pesticide use, reduced genetic diversity, the introduction of nonnative pathogens, competition with honey bees, and climate change. These issues are discussed in detail below.

2.1 Habitat Fragmentation

It has been shown that habitat fragmentation is the leading cause of bumble bee declines in Europe[10]. This trend has not been demonstrated in North American populations, at least among our most imperiled species, although there has been little research to test this hypothesis (but see Grixti et al. 2009[27]). The biggest changes in North America's landscapes since the middle of the twentieth century have resulted from modern farming techniques that enabled more intensive use of agricultural lands. These changes have very likely affected many species of bumble bees[27]. Since bumble bees nest and overwinter under or at ground level, any plowing, mowing, or other ground disturbance can destroy both nesting and overwintering sites. Moreover, conversion of extensive grasslands to monoculture landscapes throughout much of the country has removed vast areas once used as foraging grounds for bumble bees.

Because of their unique reproductive system (see Box 2, opposite) and their colonial life cycle, bumble bees are particularly sensitive to habitat fragmentation. Moreover, while bumble bees can forage and disperse over relatively long distances, isolated habitat patches are unlikely to provide a sufficient long-term solution to habitat fragmentation[4,10,20]. Some studies suggest that between 800 and 2,500 acres of suitable habitat are needed to support healthy bumble bee colonies[20], although we still know little about nesting densities and foraging ranges. Ultimately, we will need a connected network of habitat, and a large scale effort to restore habitat for our native pollinators.

2.2 Grazing

Grazing in natural areas and rangelands is a common practice throughout the United States. If not managed appropriately, the ecological impact of grazing can be severe[31]. Livestock grazing can greatly alter the structure, diversity, and growth habits of the vegetation community, which in turn can affect the associated insect community[32]. Grazing during periods when floral resources are already scarce (such as mid-summer) may result in insufficient forage being available for bumble bees, which forage into late September in some areas[33]. For example, Hatfield and LeBuhn[34] found that uncontrolled sheep grazing in mountain meadows in the Sierra Nevada removed enough flowering plants to eliminate bumble bees from some sites.

Different grazing regimes have been shown to affect bumble bee populations[33–37]. The timing and intensity of grazing, and type of livestock are all important predictors of the number of bumble bee species present on a site. It has also been demonstrated that grazing affects foraging behavior of bumble bees[35]. Sheep grazing can be particularly detrimental to bumble bees because sheep selectively eat flowers, often leaving none for foraging bees[33,34]. One study showed that grazing affected the structure of prairie vegetation by reducing the availability of flower-

ing resources, compacting the soil, and removing potential above ground nesting sites (grass tussocks)[37]. However, studies have also shown that careful and well-timed cattle grazing can positively contribute to bumble bee habitat[33].

2.3 Pesticide Use

The use of insecticides and herbicides is detrimental to a healthy community of pollinators. Insecticides, by design, kill insects and herbicides reduce floral diversity. Although pesticide use on crops and rangeland is often the primary concern, they are also widely used on natural areas to control invasive species and on recreation sites and gardens. Indeed, the greatest pesticide use (measured as pounds of active ingredient applied per acre) takes place in urban and suburban landscapes. Homeowners have access to a wide array of pesticides with little regulation of their use, and few opportunities for education about the effects of these chemicals.

In general, while pesticide labels may list hazards to honey bees, potential dangers to native bees and other pollinators are often not listed, or even evaluated. (It is worth noting that home and garden products do not carry bee warning labels, even when they contain the same chemical used on farms.) Bee larvae can be negatively affected by consuming food contaminated with pesticides[38–40]. Bumble bees are especially sensitive to die offs caused by pesticide use in the spring, the period when queens are founding colonies or colony sizes are small[10,41]. Moreover, efforts to avoid contact with honey bees by spraying insecticides in the early morning may be especially harmful to bumble bees, as they are active in cooler temperatures and lower light situations[41].

Insecticides

Insecticides, although not specifically directed at pollinators, are created to kill target insects, and consequently, can have a wide range of toxicity to bumble bees. Insecticides are widely used on agricultural lands, yards and lawns, and in natural areas throughout the United States to control both native and nonnative species. In vast areas of rangelands, native grasshoppers are targeted with a variety of pesticides[42]. In addition, overspray and drift of agricultural insecticides can affect non-target organisms in field borders[43]. Insecticides not only kill pollinators[38,44], but sublethal doses can affect their foraging and nesting behaviors[45–50], lowering reproductive success, and in turn, often preventing pollination. Because of the wide range of toxicity, the impacts of insecticides may not be immediate; lethal or sublethal effects often manifest several hours or days later. Significantly, even pesticides approved for organic agriculture can harm bees. (For more

Box 2: Extinction Vortex?

Two life history traits of bumble bees—their colony structure and method of gender determination—makes them more vulnerable to threats such as habitat fragmentation, overgrazing, pesticide use, introduced pathogens, and climate change. In small populations of bumble bees, these two traits magnify the effects of the threats, creating what is called an *extinction vortex*, a spiral of factors that all lead to decreases in bumble bee fitness, and potentially, extinction. Whether this is actually happening in bumble bee populations remains to be seen, but given the forces operating, the possibility certainly exists.

We do know that several of the species that have experienced rapid population declines in recent years have significantly lower genetic diversity than the species that are not in decline[4]. Whether this has contributed to or is a result of the decline is unclear. However, there is evidence that bumble bees are jeopardized by each individual threat described in this chapter, and these threats are exacerbated by a combination of the bumble bees' unique way of determining gender and small effective population sizes.

The increased impact of landscape changes and land management practices on bumble bees underscores the importance of providing high-quality habitat for them throughout the country. Not only will an increased area of secure habitat provide refuge for bumble bees—and in turn support more colonies—but it will also provide corridors for them to travel between habitat patches, facilitating gene flow and increasing genetic diversity.

The rusty-patched bumble bee (*Bombus affinis*) is one species that has suffered dramatic declines in recent years. (Photograph © Jen Knutson)

information, see the Xerces Society's fact sheet "Organic-Approved Pesticides," available at http://www.xerces.org/wp-content/uploads/2009/12/xerces-organic-approved-pesticides-factsheet.pdf.)

Of growing concern are systemic insecticides. These accumulate in the pollen or nectar of flowers, and thus are consumed by adult bees and brought back to the nest by foragers. This contaminated food can negatively impact developing larvae, or other adult members of the colony, reducing reproductive success. Studies have also shown that bees are particularly sensitive to neonicotinoid pesticides, even at low doses[50,51]. The use of neonicotinoids has increased dramatically since the 1990s, and because many of the documented declines of pollinator populations in North America have taken place since that time, the role of these highly toxic pesticides has been suggested as a potential cause[28]. A recent study showed a dramatic decline in bumble bee queen production with relatively low doses of a neonicotinoid[48].

Worldwide there are efforts calling for the ban of neonicotinoids because of their effect on bees; opinion articles, documentary films, and signature gathering campaigns are abundant in the U.S. and abroad. A recent summary[50] of the effects of neonicotionoid use on bees released by the Xerces Society (*Are Neonicotinoids Killing Bees?*, available from http://www.xerces.org/neonicotinoids-and-bees/) lists important unanswered questions and research directions that will be important next steps. The report recommends that regulators reassess the bee safety of all neonicotinoid pesticide products, reexamine or suspend all conditional registrations until we understand how to manage risks, and require clear labels so that consumers know that these products kill bees and other pollinators. The report also recommends that the U.S. Environmental Protection Agency adopts a more cautious approach to approving new pesticides, and uses a comprehensive assessment that adequately addresses the risks to honey bees, bumble bees, and solitary bees in all life stages.

Sunflower crops are often treated with neonicotinoid pesticides, which can accumulate in the pollen and nectar and be consumed by bumble bees. (Photograph © Eric Mader.)

Herbicides

While herbicides do not directly target insects, their effects are felt by pollinating insects as herbicides remove floral resources and above-ground nesting sites, two essential habitat components[52–55]. Just as pollinators can influence the vegetation community, changes in vegetation can have an impact on pollinators[19]. A pollinator community requires consistent sources of nectar, pollen, and nesting sites during those times that adults are active. The broadcast application of an herbicide can indiscriminately reduce floral resources, host plants, and/or nesting habitat[55]. Such a reduction in resources can cause increased pollinator mortality.

Kevan[56] noted that herbicides reduced the abundance of flowers in the mint and sunflower families in regions of France and Belgium, contributing to a decline in bumble bee populations. Kevan[56] also found that herbicide applications reduced the reproductive success of blueberry pollinators, including bumble bees, by limiting alternative food sources that can sustain the insects when blueberries are not in bloom. In contrast, Russell et al.[57] and Forrester et al.[58] found that the use of a selective herbicide combined with mechanical removal of shrubs and small trees was an effective method of maintaining power line corridors as pollinator habitat. In both studies, however, non-selective broadcast herbicides were destructive as they not only suppressed target plants, but important nectar resources as well.

2.4 Genetic Diversity

Two genetic factors may be contributing to bumble bee population declines: a colonial life cycle and a system of gender determination called haplodiploidy. Each of these factors can contribute to a low effective population size (actual number of breeding individuals) of bumble bees, but when combined with threats such as habitat fragmentation, a unique combination of factors is created that can be particularly detrimental to small populations (See Box 2 on page 7).

Because of their colonial life cycle, the abundance

of bumble bees is not a reliable indicator that the bumble bee population is diverse. Since only queens produce offspring, diversity is measured at the colony level and not at the individual level (unlike most other species). As a colony can contain more than 100 individuals, what appears to be a healthy community of bumble bees may be represented by only a few colonies, and thus represent very little genetic diversity.

Moreover, gender determination in bumble bees (and all other bees) is decided by a unique genetic system called haplodiploidy. After mating, a female bee stores the sperm in a chamber and releases it when needed. In this way she can control the gender of her offspring: fertilized (diploid; they have chromosomes from both parents) eggs develop into females and unfertilized (haploid; chromosomes from only the mother) eggs develop into males. This system works fine in large populations with high levels of genetic diversity. In a small population, however, a queen is more likely to mate with a closely related male, whose chromosomes (individual sections of DNA) are similar to hers. When this happens, even her fertilized eggs may develop as if they are unfertilized (they would be effectively haploid with two copies of the same sex gene) and develop into males. (For a more thorough review, see Goulson 2010[20].) Because they do not forage for nectar or pollen to bring back to the nest, male bees do not contribute to colony growth nor development of the larvae. They are also a "cost" to the colony because they consume food supplies during development. As a result of haplodiploidy, small populations of bumble bees are at greater extinction risk[10,59,60]. If the queen cannot produce adequate numbers of female workers (or new queens), the colony will have very low fitness, and will not persist.

2.5 Pests and Diseases

Exotic pathogens pose a threat that may be particularly significant to bumble bees in North America[4,61,62]. Over the last twenty years the commercial bumble bee industry has dramatically increased its output, largely due to demand from greenhouse tomato growers, but also from producers of berries, tree fruit, greenhouse peppers, and other crops. Two species of bumble bee have historically been used in North America for commercial rearing, the common eastern bumble bee (*B. impatiens*) and the western bumble bee. Due to heavy infections from a fungal pathogen (*Nosema bombi*) in commercial facilities, the western bumble bee is no longer being used. The only bumble bee currently reared in the U.S. for commercial use is the common eastern bumble bee.

Scientists at the University of Illinois are testing the hypothesis that an exotic strain of *N. bombi* spread from commercial bumble bees caused the decline of several wild species. For a time in the early 1990s, queens of the western and common eastern bumble bees were sent to Europe to be reared in commercial facilities there, then colonies were brought back to the U.S.[63]. It is thought that while in Europe, the North American bumble bees came into contact with a European strain of *N. bombi* that was particularly virulent in North American bees[64]. Commercial bumble bees may have transmitted this strain of *N. bombi* to wild populations; managed bumble bees routinely escape from greenhouses[61,65] and are also often used for open field pollination.

This hypothesis, originally developed by Dr. Robbin Thorp, is supported by the timing, speed, and severity of declines observed in several species of wild bumble bees, as well as the close relationship of the declining species to each other and to one of the commercial species. Four bumble bees in serious decline (western, Franklin's, rusty-patched, and yellow-banded) are very closely related (they are all in the same subgenus), suggesting a potential genetic predisposition to harm from this parasite. A recent study confirmed that the western and American bumble bees had significantly higher loads of *N. bombi* than species that are not in decline[4]. The rusty-patched and yellow-banded bumble bees also had higher rates of *N. bombi* infection, although the sample size of each was too small to include in a robust analysis[4].

Other pests and diseases that may be harmful to bumble bees, and that could potentially spread from commercial colonies to wild bees, include macroparasites

Western bumble bee (*Bombus occidentalis*) queens were taken to Europe in the 1990s for commercial breeding. It has been hypothesized that when colonies were shipped back to the U.S., they brought a microparasite with them that has now infected wild bumble bees. (Photograph © Gail Spitler.)

(nematodes, mites, dipteran and hymenopteran parasitoids), microparasites including microsporidia (*Nosema bombi* and other fungal spores), protozoans (flagellates, neogregarines), and viruses (DNA and RNA)[20,66]. It is clear that a global, and even a regional, bumble bee trade has the potential to have widespread consequences for native bumble bees. Any use of commercial bumble bees needs to be carefully considered and managed.

2.6 Competition with Honey Bees

The honey bee (*Apis mellifera*) was introduced to North America by European settlers in the early seventeenth century. The honey bee is extremely important to our agricultural system, yet its populations have declined steadily since the mid twentieth century. Many efforts to support honey bee populations are in line with bumble bee conservation. However, recent research has shown that competition with honey bees reduces bumble bee foraging efficiency, worker size[67], and reproductive success[68]. As such, bumble bees in close proximity to honey bee hives may be experiencing additional pressures in an already difficult landscape. A single honey bee hive can contain over 50,000 bees, who collectively remove hundreds of pounds of nectar and tens of pounds of pollen from an area in a single year. Whether this is testing the limits of the available flowering resources is unverified. However, there is no doubt that such a significant removal of resources must represent a substantial proportion of the available pollen and nectar, especially during a period of limited flower abundance.

Klemens and Volkmar[69] showed that the presence of honey bees force bumble bees off flowers, and change their foraging times. While reproductive success was not measured in this study, any event that causes decreased efficiency of foraging trips is likely to be detrimental for bumble bees[26].

In addition, it has been shown that pollen is a vector for disease transmission between honey bees and bumble bees[69]. Thus, where bumble bees are visiting the same flowers as honey bees, they face an increased risk of infection. Diseases from some pathogens can lead to fewer new queens produced by the colony. Since honey bees are present virtually everywhere there are flowers in North America, it is nearly impossible to avoid interactions between honey bees and bumble bees. However, if land managers have the option to limit these interactions by restricting honey bee hives from natural areas managed for biodiversity, it is strongly recommended.

Before allowing hives to be placed in sensitive natural areas, land managers should weigh the known risks that honey bees pose to bumble bees. (Photograph © Matthew Shepherd.)

2.7 Climate Change

Bumble bees may be sensitive to climate change, especially at the edges of their ranges. Species that occupy very specialized climatic niches may be at greatest risk of extinction[70]. Because bumble bees need flowering resources throughout their flight period, any changes in flowering phenology could have dramatic consequences[11]. Changes in temperature and precipitation are already occurring and may lead to unpredictable or unreliable flowering cues[71,72]. In northern and high elevation regions, early melting of the snowpack will reduce water availability in the summer, and therefore early drying out of habitat and the associated loss or reduction in bloom. A change of only a few weeks, or perhaps even a few days, of flowering phenology could have significant impacts on bumble bee reproduction. Bumble bees will be most sensitive to changes in plant phenology, or the availability of nectar and pollen, at the beginning and end of their flight seasons. Emerging queens need reliable forage in the early season, and the colony needs adequate resources at the end of the season as they produce the reproductive members of the colony (new queens and males).

3 Conservation Guidelines

There is little doubt that widespread changes in land use have had an effect on bumble bee populations. Large agricultural fields, grazing, and manicured urban areas have all significantly changed the landscape. Converting transformed land back into suitable habitat is one of the best changes that can be made for bumble bees. Such transformations may be done swiftly, but careful planning is important for creating the most beneficial habitat. The following guidelines will help land owners and managers to design meaningful projects to enhance existing habitat, and to target management practices to maintain and restore beneficial habitat for bumble bees. In most cases, these management practices should not significantly increase cost or time commitment, but instead require only increased awareness and attention to the needs of bumble bees.

3.1 Creating High-Quality Habitat

There are three things that bumble bees need in the landscape to thrive: flowers on which to forage, somewhere to nest, and a place to overwinter. Each of these habitat requirements is vital for a different phase of the bees' annual life cycle.

Pollen and Nectar Sources

Bumble bees need a rich supply of flowers during the entirety of the colony's life. They are generalist foragers and will gather pollen and nectar from a variety of flowering plants. However, individual bumble bees do show high fidelity to particular flowers within a bloom period. The flight season of different species varies, but generally queens emerge in the late winter or early spring and the colony continues through to late summer or early fall. This requirement makes bumble bees sensitive to differing management practices throughout the course of the year. Monoculture crops, grazing, mowing, and weed control can interfere with the long-term health of bumble bee populations.

Careful selection of plants that are beneficial to bumble bees is essential to creating valuable habitat. Native plants are an excellent choice to provide nectar and pollen sources. They provide several benefits:

- Bumble bees coevolved with native plants and therefore know how to use them as a resource.
- Once established, native plants typically need less maintenance from the landowner (less water, reduced use of fertilizers and pesticides).
- Native plants usually do not spread to become weedy species in natural areas.

Horticultural and other varieties can also provide pollen or nectar, especially in urban areas—but, be careful to choose heirloom varieties. Highly ornate modern or double-petaled hybrids have typically been bred for showiness, potentially at the expense of pollen or nectar. As a result, they may not provide necessary nutrients, or the nectar or pollen may be inaccessible to bees[73].

Bumble bees do have preferences for certain species of plants. Generally, they prefer flowers that are purple, blue, or yellow; they are essentially blind to the color red and won't forage on red flowers (unless there are UV cues on the petals)[74]. Having plants with a diversity of corolla tube lengths will support bumble bees with varying tongue lengths. Bumble bees also show a strong preference to perennial plants as opposed to annuals; perennials tend to have higher quantities of nectar[75].

Appendix B contains a list of native plants for bumble bees in each region of the country. The plants in each list are highly attractive to bumble bees, bloom through-

An abundance of diverse flowers that provide pollen and nectar is a key component of bumble bee habitat. (Photograph © iStockphoto/stevegeer.)

Box 3: Where Do Bumble Bees Nest?

The most comprehensive studies on bumble bee nesting habits have been done in Britain, where several nationwide nest surveys have been conducted with the help of citizen scientists[76–79]. Through these efforts scientists have been able to analyze many different nesting sites used by different bumble bee species, allowing comparison of the nesting data between and within species. While there is still much to be learned, particularly here in North America, this research has significantly contributed to our understanding of bumble bee nesting behavior.

Of interest, there is a fairly high correlation between species' use of nesting substrates and the common habitat features that are available, suggesting that bumble bees are opportunistic in nest site selection. Some species do have nesting preferences, but will take advantage of many different locations and materials. The most comprehensive study analyzed over one thousand nesting sites[76]. Of the top five nest locations—bird box, cavity in rock wall, compost pile, under building/manmade structure, hole in the ground—four were artificial structures and they represented more than three quarters of observed nests. While there may be some surveyor bias here as citizens are more likely to be looking where people live, it still means that gardens and natural areas with buildings, rock walls, bird boxes, etc. can provide significant habitat. This adds to the growing evidence that urban areas, parks, gardens, and managed natural areas can be significant refuges for bumble bees[20,37,75,76]. It also suggests that creating and conserving nesting habitat in natural areas and habitat fragments can potentially be a significant contributor to the reproductive success of bumble bees.

If you have found a bumble bee nest, please share the information with the Xerces Society, so we can continue to learn more about the nesting habits of the bumble bees in North America. Our nest survey can be found online at http://www.xerces.org/bbnest/.

Nest of yellow-faced bumble bee (*Bombus vosnesenskii*). (Photograph © Sarah Greenleaf.)

out the entire flight season, and offer a variety of bloom colors. We also considered the commercial availability of these plants, so the species listed are often available from local native plant nurseries or specialty native seed producers. Also included is a list of flowering shrubs and small trees that could be used in any planting plan. Flowering trees and shrubs can be fantastic early season resources for bumble bees and are often the only plants flowering in early spring.

Accompanying the native plant lists is a short list of bee-friendly garden plants that are available nationwide. Many varieties of these plants should be available at your local nursery, but remember to choose older varieties and those that are not highly ornate.

In addition to flowers, many bumble bee species may benefit from the presence of native bunch grasses. Bunch grasses will add multiple textures and heights to your garden or landscape and provide places for bumble bees to nest or overwinter. Many species of native bunch grasses are commercially produced in each region, and should be available at your local nursery.

For more information about selecting plants for bees, see *Attracting Native Pollinators* (Storey Publishing, 2011). You can also produce a customized plant list for your specific area (or find alternatives to those plants listed in Appendix B) by visiting our online plants database at http://www.xerces.org/lbj. This was developed in collaboration with the Lady Bird Johnson Wildflower Center and can be searched by a number of variables, including bloom time, bloom color, and region.

Nesting and Overwintering Habitat

Most bumble bees nest underground, often in abandoned holes made by ground squirrels, mice, and rats, or occasionally abandoned bird nests[76]. Some species do nest on the surface of the ground (in grass tussocks) or in empty cavities (hollow logs, dead trees, under rocks, etc.). In gardens, nests are often found in compost piles or unused bird houses. (Box 3 has more information on bumble bee nesting sites.) Queens most likely overwinter in small cavities just below or on the ground surface. They have also been noted overwintering in manmade habitat such as woodpiles, rock walls, and in sheds.

While there is still much to be learned about the nesting and overwintering biology of bumble bees, it is clear that any near-surface or subsurface disturbance of the ground is likely disastrous for bumble bee colonies or overwintering queens. This includes mowing, fire, tilling, grazing, and planting. Having large areas of land free from such practices is essential for sustaining bumble bee populations. Since bumble bees usually nest in abandoned rodent nests, it is also important to retain landscape features that will support rodent populations[77].

In addition to providing natural habitat, it is possible to build artificial nesting sites. This could include nest boxes or piles of field stones, brush, hay, or grass to provide cavities that are dry, dark, and attractive to bumble bees. The piles need not be large, but ideally would be located along edges of woodlots or hedgerows. The presence of nesting material, like cotton batting, may increase the chances of occupancy. The highest rates of occupancy for provided nesting sites (including artificial nest boxes) has only been around 30 percent, with occupancy rates normally lower than that. While this is not a high success rate, if nesting sites are limited in an area, any increase in availability could be beneficial to bumble bees. Appendix C provides details of building a nest box and placement suggestions.

3.2 Restoring and Managing Habitat

The goal of these management practices is to provide habitat that more closely resembles that in which bumble bees evolved. Land use changes over the last seventy years have created habitat that is not suited to bumble bees. For example, if a bumble bee colony grows quickly in the early season thanks to the mass bloom of a farm field or orchard, there may not be enough resources to maintain that colony after the bloom has gone to seed or fruit. Also, if a bumble bee queen chooses a nest site in habitat that will later be mowed, burned, or tilled, the colony has no chance for survival.

The following recommendations are designed to be synchronous with the bumble bee life cycle and minimize risks to colonies, while maintaining flower-rich foraging areas and secure nest sites.

Mowing, fire, and grazing are all widely used and valuable tools for maintaining the open, meadow-like conditions that bumble bees prefer. However, if done inappropriately (such as too frequently, or over too wide of an area), any of these can also remove too many floral resources and destroy nesting habitat for bumble bees, as well as harm butterflies, moths, and other invertebrates whose life cycles depend on the plants being disturbed[73]. Specific guidelines follow for each of these three management techniques, but there are two key principals that apply irrespective of which is being employed:

- Do not treat the entire site at one time, and
- When a treatment is being applied, do not treat more than one third of the site per year.

Mowing

Grassy areas such as meadows, forest edges, hedgerows, and lawns may all be subject to mowing. Research in Britain has shown that unmanaged meadows and gardens with a high proportion of grass and different layers of habitat have the highest diversity of bumble bees[73], and that mowed sites have significantly fewer bumble bee nests[80]. If mowing is deemed necessary, please adopt the following guidelines.

Any management activity will change the habitat structure or diversity, and should be applied with care to avoid negative impacts and maximize the benefits to bumble bees. (Photograph © Heritage Seedlings/Lynda Boyer.)

- Leave one or more patches—as large as possible—of meadow, lawn, or edge habitat unmowed for the entire year.
- If you need to mow during the flight season (March–September), try to create a mosaic of patches with structurally different vegetation.
- Mow at the highest cutting height possible to prevent disturbance of established nests or overwintering queens. A minimum of 12–16 inches is ideal.

Fire

Fire is an important management tool for many meadows and other open habitats, but requires care to avoid disturbance to plant and animal populations. The following recommendations will maximize the benefit to bumble bees.

- Only burn a specific area once every 3–6 years.
- Burn from October through February.

- Burn small sections at a time.
- No more than one third of the land area should be burned each year.
- If possible mow fire breaks that will result in patches of unburned or lightly burned areas to serve as refuge for animals within the burn area.
- Avoid high intensity fires.

Grazing

A common practice in natural areas and agricultural landscapes, grazing has been shown to have dramatic effects on the structure, diversity, and growth habits of plants. When carefully applied, grazing can be beneficial for limiting shrub and tree succession, encouraging the growth of nectar-rich plants, and providing the structural diversity that creates nesting habitat. However, grazing animals have the potential to remove flowering resources, as well as trample nesting and overwintering sites—and in turn harm the animal communities that depend on them[52].

Grazing is usually only beneficial at low to moderate levels and when the site is grazed for a short period followed by ample recovery time. We make the following general recommendations, but stress the importance of assessing local and historical conditions before implementing a plan.

- Grazing management strategies should be completed according to the characteristics of the site and the animals being used (see https://attra.ncat.org/attra-pub/livestock/pasture.html).
- Grazing on a site should occur for a short period of time, giving an extended period for recovery.
- Grazing should only occur on approximately one third of the property each year.
- Establish exclosures and rotate grazing to allow recovery of the vegetation community.

Tillage

Any surface or subsurface disturbance can be harmful to bumble bee colonies. In order to ensure the long-term health of bumble bee populations at least some areas under management must remain permanently free of tillage. These areas could be fence margins, hedgerows, debris piles, ditches, compost heaps, etc. Nesting surveys in Britain showed that gardens and linear features like hedgerows (i.e., places free from tillage) provided important bumble bee nesting habitat[76].

3.3 Using Pesticides

Any use of pesticides can affect bumble bees. Decision-making systems such as Integrated Pest Management can be important for developing less toxic responses to pests, and ensure that actual pest damage is taking place before chemicals are used. It is important to note that it is not just cropland and rangeland that experience high use and concentrations of pesticides. Surveys in urban streams indicate that urban and suburban use of pesticides may be greater and potentially more detrimental. This is likely because the pesticides being applied in agricultural settings are being done by trained professionals, while those applying pesticides at home are often using the pesticides at a far greater concentration than necessary; allowable concentrations are often much higher for home use[50], and lack any type of warning to protect bees.

We strongly recommend against the use of pesticides whenever possible, but also realize that targeted herbicide and insecticide applications can be effective management tools to control crop pests and invasive species. For situations when pesticides must be used, we make the following recommendations.

- Follow the manufacturer's directions.
- Choose the least toxic option:
  - Avoid dusts and microencapsulated products.

Pesticides should always be applied with care. For herbicides, equipment such as a weed wipe allows more precise application, avoiding nontarget plants and spray drift. (Photograph © Heritage Seedlings/Lynda Boyer.)

Case Study: University of Wisconsin – Madison Arboretum

Located in the middle of Madison, WI, the University of Wisconsin – Madison Arboretum attracts about one million people annually. Scientists, land managers, students, gardeners, community members, and visitors from all over world use the Arboretum for research, workshops, classes, tours, field trips, or simply to enjoy the nearly twenty miles of hiking trails. The land was once agricultural fields and pastures, but thanks to extensive restoration efforts has been transformed into a diverse mix of ecological communities representing the native plant communities of Wisconsin. The Arboretum's 1,200 acres are home to savannas, prairies, deciduous and conifer forests, and wetlands, as well as horticultural gardens featuring both native and ornamental plantings.

This diversity of habitats alone benefits bumble bees, as there are many different plant communities and hundreds of native species growing in the remnant and restored habitat of the Arboretum. These diverse communities provide foraging resources from the early-spring flowering of willows in wetlands to early-autumn bloom of goldenrods in prairies. In addition to the diversity of flowering resources, the heterogeneity of the landscape provides a diversity of nesting opportunities ranging from old stone and rock walls to decomposing logs, rodent holes, and grass tussocks.

Ten species of bumble bees have been identified at the Arboretum—including the rusty-patched bumble bee—an impressive list given the relatively small parcel of land and the fact that it exists within a urban area.

Although this diversity of bumble bees can be attributed in part to the variety of habitats within the Arboretum, it can also be ascribed to the use of a range of land management practices that align with bumble bee life history characteristics. To help maintain high-quality bumble bee habitat, the Arboretum:

- Plants native species known to be attractive to bumble bees and monitors which plants bees are using;
- Documents bumble bee species that forage and/or nest at the Arboretum to inform land management;
- Maintains blooming plants throughout the flight season (which in Madison is March to September);
- Burns rotationally, in small parcels at a time, and always leaves refuges for bumble bees;
- Removes invasive species by hand, or by using targeted herbicide application;
- Uses insecticides rarely;
- Leaves areas with leaf litter, brush, fallen logs, and bunch grasses used for nesting and overwintering; and
- Retains snags and leaves downed wood for nesting and overwintering sites.

Wild indigo prairie at the arboretum. (Photograph © Eric Mader.)

The Arboretum also has an active education and outreach program targeting gardeners, students, community members, and staff. Through this it advocates for bumble bees and encourages bee-friendly practices within and beyond the Arboretum. For example, presentations, tours of the native plant garden, and volunteer gardening sessions provide chances for the general public to learn about bees. (This is an on-going commitment; the Arboretum will continue to hold bumble bee activities for families, such as bumble bee spotting walks.) The Arboretum also hosts events for land management professionals, such as a 2010 Xerces Society short course on native pollinators for land managers and agency staff, and in 2012, an in-depth workshop for Arboretum employees, volunteers, and partners from UW–Madison and state agencies. The Arboretum has also initiated a multi-year citizen science monitoring project to document and photograph bumble bees in its many habitats.

Through its active management and outreach, the Arboretum has established itself as a regional center for bumble bee conservation. These efforts highlight the significance of bumble bees in the landscape and generate public interest in bumble bee conservation. The land is a refuge for both common and imperiled species alike. The Arboretum not only recognizes how important their land is for bumble bees, but also how important bumble bees are for maintaining healthy plant populations and ecosystems.

- See Riedl et al.[81] for more information.

- Use the least concentrated application possible.
- Apply the pesticide as directly and locally as possible.
- Apply when bumble bees are not active (keeping in mind that bumble bees can fly at cold temperatures, and are often active in the early morning and early spring):
  - Late fall or winter.
  - At dusk or at night.
- Do not spray or allow drift to move onto field margins or boundaries.
- Do not apply pesticides when plants are in bloom.
- Reduce spray drift:
  - Avoid aerial spraying and mist blowers.
  - Spray on calm days (winds between 2 and 9 mph) to minimize spray drift from targeted applications.
- Avoid the use of systemic pesticides, such as neonicotinoids.

3.4 Commercial Use of Bumble Bees

Increasingly, as the cost of honey bee rental rises and the benefits of bumble bees as pollinators are realized, bumble bees are being shipped throughout the world for pollination of greenhouse and field crops. Pests escaped from commercially reared bumble bees may have led to the dramatic decline of the western, rusty-patched, American, yellow-banded, and Franklin's bumble bees. Currently, there is only one species of bumble bee being used for managed pollination, the common eastern bumble bee, which is native to the eastern U.S. The use of this species in the western U.S.—outside of its native range—poses considerable risk to native bumble bees in the in Rockies and westward[82]. The common eastern bumble bee may spread pathogens to wild bumble bees, or it may become established in the wild and outcompete native species for nest sites or floral resources[61,65]. Currently, only Oregon and California restrict the importation of nonnative bumble bees (including the common eastern bumble bee) into the state, with Oregon prohibiting all importation and California allowing them to enter the state for greenhouse use only.

Any use of commercially reared bumble bees for crop pollination should focus on minimizing the exposure of wild native species to managed species. We recommend the following.

- Do not purchase commercial bumble bees for use outside of the native range of the species.
  - If you live in western North America, do not purchase commercial bumble bees until native, disease-free colonies become available.)
- Only use commercial bumble bees in greenhouses; do not use them for open-field crops.
- Screens should be placed over windows, vents, and other openings in greenhouses to prevent commercial bumble bees from escaping and interacting with wild bumble bees.
- Commercially acquired colonies should be killed (for example, by being placed in a freezer overnight) after their period of use and NOT released into the wild.

3.5 Honey Bees

Honey bees may pose a significant threat to the reproductive success of bumble bees[66,68]. While honey bees are experiencing their own population threats, and warrant special attention beyond the scope of these guidelines (although they will also benefit from the creation and management of habitat), for bumble bees we urge land managers to err on the side of caution. Since bumble bees are native to North America and native bees are often more effective pollinators of native plants, we make the following recommendations for natural areas.

- We recommend that land managers discourage the placement of honey bee hives in natural areas, especially those with rare or unique habitats.
- If this recommendation cannot be followed, we recommend that honey bee hives be placed as far as practicable from areas receiving specialized management treatment for bumble bees.
  - Especially important will be to distance honey bee hives from potential bumble bee nesting sites, such as unmowed and untilled areas, old rock walls, fencerows or hedgerows, treed field margins, and hollow trees.
  - Where possible, distances greater than 0.6 miles (1 kilometer) will substantially reduce the competitive effects of managed hives on bumble bees.

4 Conclusions

Bumble bees are essential pollinators in the wildlands, agricultural landscapes, and urban areas of North America, yet the population trends of many species are alarming. Regardless of the ultimate cause of the observed declines, extant populations of these imperiled bumble bees are likely small and still threatened by a variety of land management practices. It is critically important to protect the remaining populations of bumble bees from the risks they face.

Protecting, restoring, enhancing, or creating new bumble bee habitat is the best way to conserve populations of these indispensable animals. While coordinated efforts are certainly necessary at a larger, landscape scale, individual landowners can create small refuges by adopting the guidelines presented in this document, making a direct contribution to bumble bee conservation while the larger efforts take shape. Every property has the potential to support important habitat for bumble bees.

By understanding the habitat requirements and the life cycle of bumble bees, landowners will not only be able to better manage habitat for bees, but will also have much greater awareness of the pollinators that are using their property. We hope that these guidelines will inspire you to take action, whether it is in an urban yard, suburban greenspace, farm, or natural area. We also hope that you will take the opportunity to get to know your local bumble bees, and encourage you to talk to your neighbors and local community organizations about protecting them. Increased awareness of our pollinators and their needs will make us all better stewards of the land.

Bumble bees thrive in areas with plentiful, diverse flowers and secluded places to nest or overwinter. However, good habitat for bumble bees can be provided on small plots of land, so anyone can contribute to protecting these essential pollinators. (Photograph © iStockphoto/stevegeer.)

Appendix A. Bumble Bee Identification Guides

The identification guides in this appendix cover four regions of the United States: California and the Pacific Northwest, Rocky Mountains and the Southwest, Great Plains and the Great Lakes states, and the eastern U.S.

Each guide includes common bumble bees of that region, as well as some imperiled species and those for which there are documented population declines. We have only included diagrams of the females of each species, which are most likely to be seen visiting flowers. These guides are not comprehensive; some species pictured have varieties with different coloration.

To help identify the declining bumble bees in North America, the Xerces Society produced three regional pocket guides. These can be downloaded at www.xerces.org/bumble-bee-identification/.

In addition, *Bumble Bees of the Eastern United States*, and its companion, *Bumble Bees of the Western United States* cover all species and color forms. These guides were produced by the U.S. Forest Service and the Pollinator Partnership. Links to both books are also at www.xerces.org/bumble-bee-identification/.

There are also two web sites that will aid in identifying bumble bees: www.discoverlife.org and www.bugguide.net.

The Xerces Society has a citizen science project to find rare bumble bees. If you believe you have seen any of the imperiled species (those highlighted in these guides and featured in Xerces' pocket guides), contact Xerces staff at bumblebees@xerces.org. Please include a photograph for verification purposes.

Four Species of Particular Concern

Western bumble bee (*Bombus occidentalis*). (Photograph © Pat Michaels.)

Rusty-patched bumble bee (*Bombus affinis*). (Photograph © Johanna James-Heinz.)

American bumble bee (*Bombus pensylvanicus*). (Photograph © Bryan E. Reynolds.)

Yellow-banded bumble bee (*Bombus terricola*). (Photograph © Leif Richardson.)

California and the Pacific Northwest

! marks species of particular concern

Two-form bumble bee (*Bombus bifarius*)

Coastal form

Mountain and northern form

California bumble bee (*Bombus fervidus* ssp. *californicus*)

Fuzzy-horned bumble bee (*Bombus mixtus*)

! **Sonoran bumble bee (*Bombus pensylvanicus* ssp. *sonorus*)**

Black-tailed bumble bee (*Bombus melanopygus*)

Mountain and northern form

Coastal form

Yellow-faced bumble bee (*Bombus vosnesenskii*)

! **Western bumble bee (*Bombus occidentalis*)**

Common form

Central coastal California form (rare)

! **Franklin's bumble bee (*Bombus franklini*)**

Rocky Mountains and the Southwest

! marks species of particular concern

Two-form bumble bee (*Bombus bifarius*)

Coastal form

Mountain and northern form

Yellow bumble bee (*Bombus fervidus*)

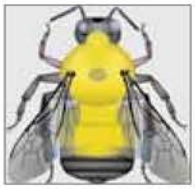
White-shouldered bumble bee (*Bombus appositus*)

! **Sonoran bumble bee (*Bombus pensylvanicus* ssp. *sonorus*)**

Nevada bumble bee (*Bombus nevadensis*)

Hunt's bumble bee (*Bombus huntii*)

Morrison's bumble bee (*Bombus morrisoni*)



! **Western bumble bee (*Bombus occidentalis*)**

Common form

Rocky Mountain form

Great Plains and the Great Lakes States

! marks species of particular concern

Yellow bumble bee (*Bombus fervidus*)


Southern plains bumble bee (*Bombus fraternus*)


Black-and-gold bumble bee (*Bombus auricomus*)


! **American bumble bee (*Bombus pensylvanicus*)**


! **Yellow-banded bumble bee (*Bombus terricola*)**


Common eastern bumble bee (*Bombus impatiens*)


Two-spotted bumble bee (*Bombus bimaculatus*)


Brown-belted bumble bee (*Bombus griseocollis*)


! **Rusty-patched bumble bee (*Bombus affinis*)**


Eastern United States

! marks species of particular concern

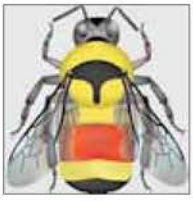
Common eastern bumble bee (*Bombus impatiens*)


Brown-belted bumble bee (*Bombus griseocollis*)


Half-black bumble bee (*Bombus vagans*)


! **American bumble bee (*Bombus pensylvanicus*)**


Tri-colored bumble bee (*Bombus ternarius*)




Two-spotted bumble bee (*Bombus bimaculatus*)


! **Rusty-patched bumble bee (*Bombus affinis*)**


! **Yellow-banded bumble bee (*Bombus terricola*)**


Appendix B. Plants for Bumble Bees

This section contains a series of regional lists of native plants that are highly attractive to bumble bees and which together provide bloom throughout the entire flight season and offer a variety of colors. Also included is a list of flowering shrubs and small trees that could be used in any planting plan. Flowering trees and shrubs can be fantastic early season resources for bumble bees and are often the only plants flowering in early spring.

Accompanying the native plant lists is a short list of garden plants that are available nationwide. We recommend that you choose heirloom varieties or those that are not highly ornate.

In addition to flowers, bumble bees may benefit from bunch grasses, which add texture and height to your garden or landscape and provide places for bumble bees to nest or overwinter.

For more information about selecting plants for bees, see *Attracting Native Pollinators* (Storey Publishing, 2011). You can also produce a customized plant list for your area by visiting our online plants database at http://www.xerces.org/lbj. Developed in collaboration with the Lady Bird Johnson Wildflower Center, this can be searched by a number of variables, including bloom time, bloom color, and region.

Pacific Northwest

(Oregon, Idaho, Washington)

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Lacy phacelia	*Phacelia tanacetifolia*								
California poppy	*Eschscholzia californica*								
Lance selfheal	*Prunela vulgaris* ssp. *lanceolata*								
Bigleaf lupine	*Lupinus polyphyllus*								
Royal penstemon	*Penstemon speciosus*								
Showy milkweed	*Asclepias speciosa*								
Nettle-leaf horsemint	*Agastache urticifolia*								
Coyote mint	*Monardella odoratissima*								
Nuttall's sunflower	*Helianthus nuttallii*								
Canada goldenrod	*Solidago canadensis*								

California

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Lacy phacelia	*Phacelia tanacetifolia*								
Carmel ceanothus	*Ceanothus griseus*								
California poppy	*Eschscholzia californica*								
Bigleaf lupine	*Lupinus polyphyllus*								
Nootka rose	*Rosa nutkana*								
Showy milkweed	*Asclepias speciosa*								

California (continued)

(Plant)		(Bloom Period and Color)							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Nettle-leaf horsemint	*Agastache urticifolia*								
Coyote mint	*Monardella odoratissima*								
Nuttall's sunflower	*Helianthus nuttallii*								
Canada goldenrod	*Solidago canadensis*								

Southwest

(Arizona, New Mexico, Nevada, west Texas)

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Lacy phacelia	*Phacelia tanacetifolia*								
White honeysuckle	*Lonicera albiflora*								
Creosote bush	*Larrea tridentata*								
California poppy	*Eschscholzia californica*								
Golden prairie clover	*Dalea aurea*								
Arrowleaf balsamroot	*Balsamorhiza sagittata*								
Silvery lupine	*Lupinus argenteus*								
Showy milkweed	*Asclepias speciosa*								
Beebalm	*Monarda fistulosa*								
Canada goldenrod	*Solidago canadensis*								

Rocky Mountain States

(Colorado, Montana, Utah, Wyoming)

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Twinberry honeysuckle	*Lonicera involucrata*								
Large-flowered penstemon	*Penstemon grandiflorus*								
Purple prairie clover	*Dalea purpurea*								
Arrowleaf balsamroot	*Balsamorhiza sagittata*								
Nootka rose	*Rosa nutkana*								
Beebalm	*Monarda fistulosa*								
Showy milkweed	*Asclepias speciosa*								
Silvery lupine	*Lupinus argenteus*								
Nettle-leaf horsemint	*Agastache urticifolia*								
Smooth blue aster	*Symphyotrichum laeve*								

Great Plains States

(North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, east Texas, Minnesota, Iowa, Missouri)

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Spiderwort	*Tradescantia ohiensis*								
Purple prairie clover	*Dalea purpurea*								
Smooth penstemon	*Penstemon digitalis*								
Beebalm	*Monarda fistulosa*								
Butterflyweed	*Asclepias tuberosa*								
Narrowleaf mountain mint	*Pycnanthemum tenuifolium*								
Showy goldenrod	*Solidago speciosa*								
Bottle gentian	*Gentiana andrewsii*								
Tall blazing star	*Liatris aspera*								
New England aster	*Symphyotrichum novae-angliae*								

Great Lakes States

(Wisconsin, Michigan, Ohio, Illinois, Indiana)

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Spotted geranium	*Geranium maculatum*								
Showy beardtongue	*Penstemon cobaea*								
Sundial lupine	*Lupinus perennis*								
Butterflyweed	*Asclepias tuberosa*								
Beebalm	*Monarda fistulosa*								
Field thistle	*Cirsium discolor*								
Narrowleaf mountain mint	*Pycnanthemum tenuifolium*								
Tall blazing star	*Liatris aspera*								
Showy goldenrod	*Solidago speciosa*								
Bottle gentian	*Gentiana andrewsii*								
New England aster	*Symphyotrichum novae-angliae*								

Northeast

(Connecticut, Pennsylvania, Massachusetts, Maine, New Hampshire, New Jersey, New York, Rhode Island, Vermont)

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Spotted geranium	*Geranium maculatum*								
Dutchman's breeches	*Dicentra cucullaria*								
Sundial lupine	*Lupinus perennis*								
Smooth penstemon	*Penstemon digitalis*								
Beebalm	*Monarda fistulosa*								
Butterflyweed	*Asclepias tuberosa*								
Field thistle	*Cirsium discolor*								
Narrowleaf mountain mint	*Pycnanthemum tenuifolium*								
Blue giant hyssop	*Agastache foeniculum*								
Showy goldenrod	*Solidago speciosa*								
New England aster	*Symphyotrichum novae-angliae*								

Southeast

(Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia)

Plant		Bloom Period and Color							
Common name	**Scientific name**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Wild azalea	*Rhododendron canescens*								
Spotted beebalm	*Monarda punctata*								
Sundial lupine	*Lupinus perennis*								
Swamp rose	*Rosa palustris*								
Butterflyweed	*Asclepias tuberosa*								
Common buttonbrush	*Cephalanthus occidentalis*								
Field thistle	*Cirsium discolor*								
Narrowleaf mountain mint	*Pycnanthemum tenuifolium*								
Tall blazing star	*Liatris aspera*								
Great blue lobelia	*Lobelia siphilitica*								

Nationwide Small Trees and Shrubs

(E = east of the Rockies; W = west of the Rockies; no mark = nationwide)

Plant		Bloom Period and Color				
Common name	**Scientific name**	**Spring**	**Early Summer**	**Mid Summer**	**Late Summer**	**Fall**
Willow	*Salix* spp.					
New Jersey tea (E)	*Ceanothus americanus*					
Rhododendron	*Rhododendron* spp.					
Redbud	*Cercis* spp.					
Twinberry honeysuckle (W)	*Lonicera involucrata*					
Raspberry	*Rubus* spp.					

Nationwide Garden Plants

(Note that many of these are not natives, so should not be used outside of gardens or formal landscaping.)

Plant		Bloom Period and Color				
Common name	**Scientific name**	**Spring**	**Early Summer**	**Mid Summer**	**Late Summer**	**Fall**
Beardtongue/penstemon	*Penstemon* spp.					
Lupine	*Lupinus* spp.					
Borage	*Borago officinalis*					
Catnip	*Nepeta* spp.					
Coneflower	*Echinacea* spp.					
Rosemary	*Rosmarinus* spp.					
Russian sage	*Perovskia atriplicifolia*					
Oregano	*Origanum* spp.					
Red clover	*Trifolium pratense*					
Sunflower	*Helianthus annus*					
Lavender	*Lavandula* spp.					
Goldenrod	*Solidago* spp.					

Appendix C. Nest Box Construction

There is no required size nor materials for a bumble bee nest box. Bumble bees are opportunistic in nest site selection, and will occupy all manner of cavities, from abandoned rodent holes to upturned flower pots and out-of-service watering cans.

It is important to note that occupancy rates of artificial nest boxes have been quite low (less than 30%) so don't expect all nest boxes to be occupied.

Construction

Wood is probably the easiest material to work with when making a nest box. We recommend that you use preservative-free lumber. The main features of a successful box (also shown in the photograph below) are:

- Internal dimensions of about 7" x 7" x 7".
- Joints held by screws or nails, and sealed with glue to make the box waterproof.
- Small ventilation holes at the top of each edge, covered with screening to deter ants.
- Quarter-round molding on the bottom of the roof to create a rim that will fit around the top of the box and prevent rain from dripping inside.
- Entrance made from ¾" plastic pipe or tubing.
- 2–3 inch depth of upholsterer's cotton placed inside as bedding.
- A detachable roof, so the box can be cleaned.

Placing the Nest Box

Place the nest in a dry area that has obvious landmarks to aid bee navigation as they return from foraging bouts. Select an undisturbed location, i.e., somewhere you won't be mowing and people don't regularly walk. The nest should be on the ground or slightly buried with soil or straw, even if only the tube entrance is buried. Install the next box in late winter or very early spring, when queens have emerged and are looking for an appropriate nesting site. Be patient, it may take weeks (or even several years) before a queen occupies the nest.

Nest Monitoring

Many species of bumble bees are docile and will allow you to lift the lid and check inside the nest. If you plan to do this, install a clear plastic top (Plexiglass ceiling) to the box to avoid accidentally disturbing the hive. This will be covered by the roof. Be careful when inspecting the hive; do not jar the box as even docile species may feel threatened by sudden movements.

Maintenance

In late fall or winter you can take all of the boxes back inside. Remove the old nests, clean the boxes with a mild bleach solution or other disinfectant (to prevent disease and parasite transmission), and make any necessary repairs. The boxes can be placed again the following spring with fresh nesting material.

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