UMASS AMHERST

a

A Review on Bees

Northeast Crops Edition

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All about bees and how we can help!

Bees pollinate our delicious crops, the plants we use to feed livestock, and beautiful wildflowers that create not only scenery for us, but food and habitat for wildlife. Their contribution to the ecosystem and to humans is immense.

Sadly, many of the 20,000 species of bees in the world are declining. Scientists suggest this decline may be due to a combination of things particularly, the rapid environmental changes in the last three decades.

Bees need our help. Here, we provide an overview of bee ecology and behavior. For conservation-minded people, we present a section on the plants and habitat that provide bees with essential resources.

Misconceptions

Telling the difference among flies, wasps, and bees is not as easy as it sounds. These groups of insects are quite similar, and even experts get it wrong sometimes.

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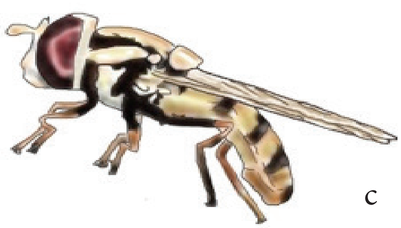
Bees have two pairs of wings, their antennae tend to be longer than flies, and most have more hair and wider legs than flies and wasps.



c

Flies often have triangular heads from above, short thick antennae, large forward facing eyes, and only one wing on each side of their body.

d

Wasps are mostly hairless, thin, have two pairs of wings, and have narrow waists. When flying, many wasps have two thin long legs that hang down.

"All bees are aggressive."

Most bees are solitary, do not defend a nest, and would only sting if pressed, for example if caught in clothes or between fingers. Honey bees, which form large colonies, often warn before they sting, bumping into the annoyance with their bodies. Honey bees are more aggressive to humans if one is standing near their colony.

"Honey bees sting multiple times."

Honey bees are the only species of bee with a barbed stinger. The stinger often gets lodged in skin and rips from the bee's abdomen, causing its death. Other species do not have barbed stingers, so the same individual can sting multiple times.

"All bees live in colonies."

Honey bees, bumble bees, and some species of sweat bees are eusocial. Eusocial bees share a nest and related workers cooperate to perform duties. However, most other species of bee are solitary or communal.

"All bees make honey."

In North America, only honey bees make honey. Other bees, like bumble bees, store nectar but the resulting substance is different from the stored nectar of honey bees.

Fly on left and right, bees in the middle

Check out bee groups and images at Native Bees of North America (www.bugguide.net.anthophila)

Carpenter bees

Large carpenter bees resemble bumble bees but are solitary insects that nest in wood. One can identify large carpenter bees by their size and shiny black abdomen. The Eastern carpenter bee (*Xylocopa virginica*) is common throughout eastern United States.

f

Carpenter bees hibernate in the winter and mate in the spring. The mated females lay their eggs in 6-8 chambers in tunnels they create in wood. New adults emerge in August, forage to prepare for winter, and hibernate in tunnels. Carpenter bees may be encountered in human areas, such as barns or woodsheds. Males, which have a whitish-yellow marking on the face and cannot sting, patrol the area around nests. The males often aggressively approach people that come into their territory.

Sweat bees (Halictidae)

Bees in the family Halictidae are sometimes called sweat bees because some species are attracted to human sweat. Most nest in the ground, though some nest in wood. Some species are social, having one queen that lays eggs and workers that help each other. Some species are cleptoparasites, meaning they steal resources from other bees. The rest are solitary, meaning each female lays and rears her own young.

Sphecodes (cleptoparasites), *Lasioglossum, and Halictus* are common and are often dark bodied. There is also a group of green sweat bees that includes *Agapostemon, Augocloropsis, Augochlora,* and *Augochlorella.* These are common bees that have all or part of the body a bright racing-car green. In some subfamilies in the Halictidae both sexes overwinter, but in others, only mated females overwinter. In the spring or summer, the bees emerge and mate (if not already mated) and begin foraging, digging nests, and laying eggs.

Lasioglossum leucozonium

g

Agapostemon

h

Augochlorella aurata

i

Sphecodes dichrous

j

Terms

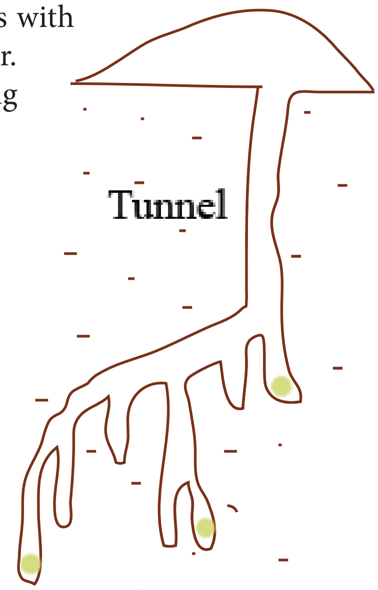
Social: species of bees where typically one female lays eggs and the rest of the colony is made up of workers that carry out nest duties cooperatively

Solitary: species of bees where the female founds her own nest and raises her own offspring. Most wild bees are solitary.

Cleptoparasites: species that steal resources from other species, for example cuckoo bees, which lay eggs in the nest of another bee

Mining bees (Andrenidae)

Mining bees build their nests in the ground and are solitary. They create tunnels with chambers at the end for brood. Each chamber contains a mixture of pollen and nectar. The egg develops into a larva, then overwinters in the tunnel until the following spring or summer.



Derivative of image on bumblebee.org

Calliopsis andreniformis

Andrena carlini

Mason bees (*Osmia* and others)

Some *Osmia* species make their nests in hollow twigs, existing cavities, or the ground. They use mud to make compartments between each laid egg and then seal the end. These bees can be metallic green, metallic blue, or black and carry pollen loads on their abdomen. Females are solitary and each makes her own nest. Males are the first to emerge, waiting for mates to appear. Mated females search for a nest site and start gathering pollen and nectar to feed their young. Newly developed mason bee adults overwinter until the following spring or summer.

Artificial *Osmia* nests

Osmia virga

Osmia pumila

Leafcutter bees (*Megachile* spp.)

Leafcutter bees cut circular shapes out of leaves and use the pieces within their nests. Most species build their nests in wood, soft or hollow stems, the ground, or in any cavity they find (like holes in concrete) or material they can easily excavate. Like mason bees, leafcutter bees collect pollen on the underside of their abdomens instead of on their legs like many other bees. Most species are solitary and each female makes her own nest. Each egg has a separate chamber with food for the developing bee. In most species, at the end of the season, newly developed adult bees overwinter until the following spring or summer.

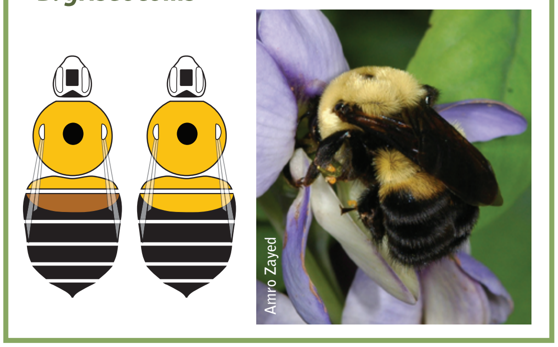
European honey bee *(Apis mellifera)*

Honey bee workers are about ½ inch in size and golden yellow to brown in color. Honey bees are not native to the United States and were introduced by European colonists in the 1600s. Their biology is different from the majority of wild bees. They are social and within the colony, there is one long-lived reproductive queen and many non-reproductive workers that cooperate to complete colony duties. They form very large colonies that survive over the winter on stores of honey and pollen.

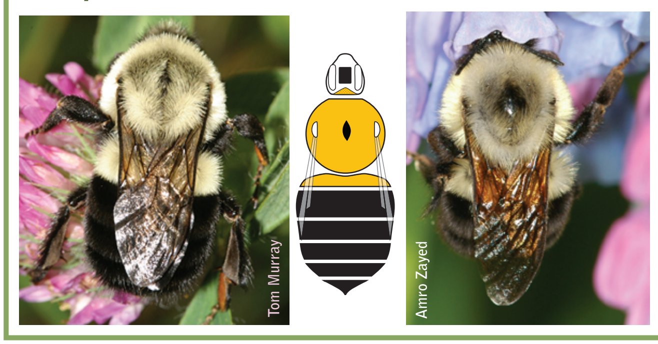
Bumble bees *(Bombus* spp.*)*

Bumble bees are relatively large and furry when compared with other bees. They are mostly black and yellow, but can have some white or orange coloration. There are about 25 species in eastern United States. *Bombus impatiens,* the common Eastern bumble bee is one of the most abundant species in the east. When compared to other species, it has a single yellow band on the abdomen and all the rest is black. For more information on bumble bees, see pages 6 and 8.

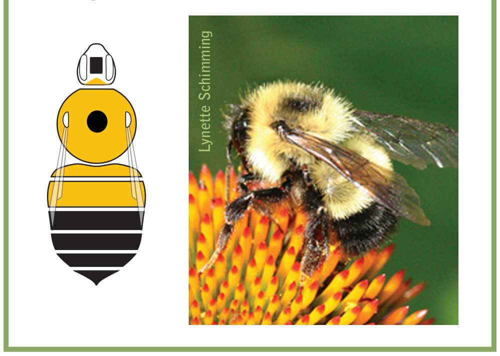
B. griseocollis



B. impatiens

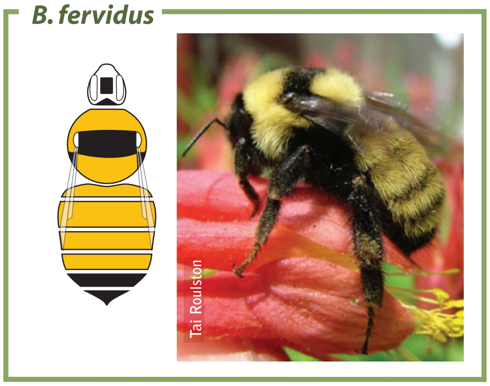


B. vagans

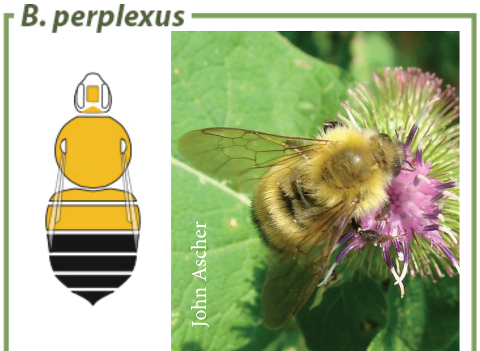


B. bimaculatus

B. fervidus



B. perplexus



Unlike female bumble bees, males have yellow hairs on their faces.

Many species of bees nest in holes in the ground.

Some species dig their own holes or use rocks and mud to build nests.

Some use existing cavities in twigs, rocks, beetle burrows, etc.

Hive-building bees typically nest between rocks, in hollow tree stumps, or in abandoned rodent holes.

Mining bee

Bumble bee

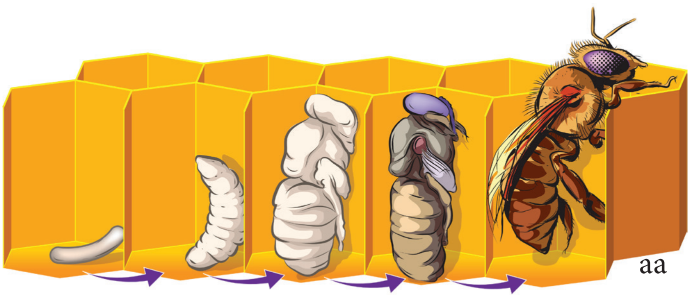
Carpenter bee

Honey bee

Sweat bee

On right, bottom image. *Augochlora pura* nest in rotting wood, dissected to show tunnels. Adult female is shown with developing larvae (immatures) and in upper part of image, some pollen. Note that the large majority of sweat bees create nests in the ground.

The bee life cycle



Reproductive females produce eggs, which are either unfertilized (producing a male) or are fertilized (producing a female). All individuals undergo complete metamorphosis. During development, larvae eat pollen until they are large enough to pupate, and then emerge as an adult bee. Depending on the species of bee, they will emerge anytime between February and September. For honey bees and bumble bees, it takes around 21 days for an egg to develop into an adult worker bee.

Voltinism-number of generations/year

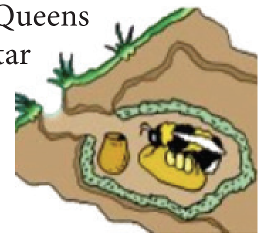
In the Northeast, many wild bee species have a single generation per year, while others have two generations. Rarely, 3-4 generations are observed, for example, in the green sweat bee, *Augochlora pura*.

Tongue lengths

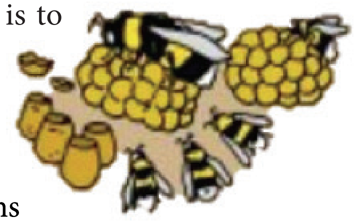
Different species of bees have different tongue lengths. Short-tongued bees usually visit shallow flowers and longer tongued bees visit flowers with long corollas.

Bumble bee life cycle

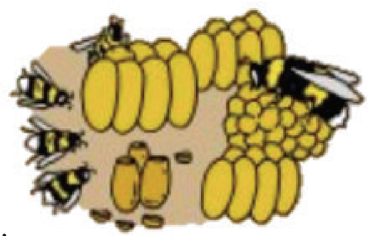
Bumble bee queens emerge in early Spring. They feed on early-blooming plants, and then look for a nest, usually a hole underground. Queens make a ball from pollen and nectar and lay eggs into the mixture. Queens incubate the eggs for a couple of weeks.



Once those eggs develop into adults, these new female workers collect pollen and nectar to provision the nest. The queen's only job now is to lay more eggs. The workers take advantage of used cells to store pollen or nectar. Compared to the honey bee colony, which may have tens of thousands of workers, depending on species, the bumble bee hive will have anywhere from only a few dozen to 100s of workers at its peak size.



Near the end of the colony cycle, new queens are produced and the old queen lays unfertilized eggs that become males. Both males and new queens leave the nest and generally do not return. The males may wait for queens on flowers. New queens fill up on reserves to prepare for hibernation.

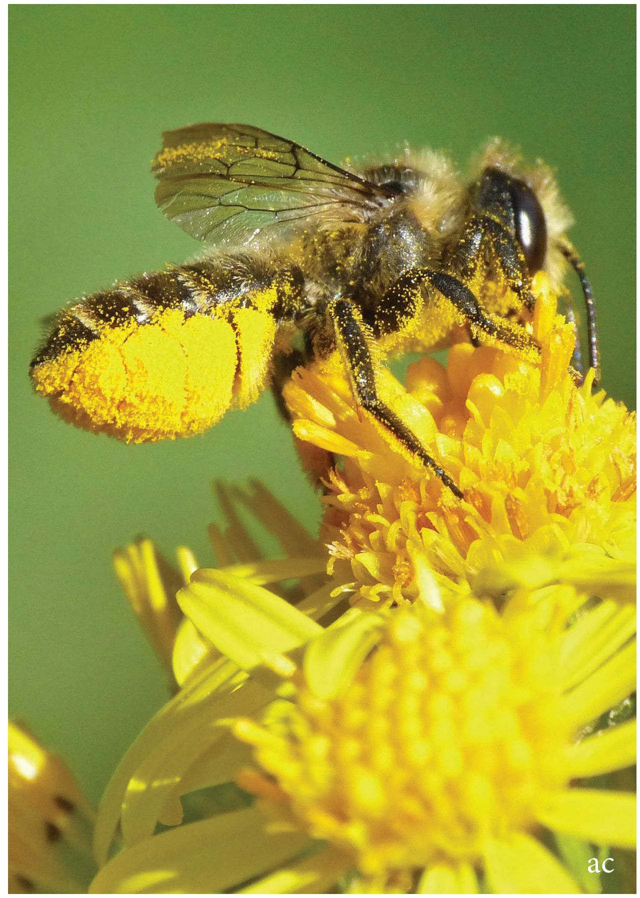


All workers, the old queen, and males die at the end of the season. The mated new queens overwinter and establish new colonies.

Illustrations by Koppert Biological Systems

Nectar provides carbohydrates and a water source for bees. Bees are pickier about the plants they collect pollen from than those they collect nectar from. Bumble bees frequently visit plants in the family Asteraceae (like heath aster or New England aster) and Lamiaceae (like garden sage, catmints, or lavender), but they rarely collect pollen from these plants.

Pollen is the main source of protein, essential amino acids, lipids, sterols, and cholestrol for most species of bee. Different plants have different levels of these compounds. It has been shown that the species of plants around a colony can impact larval growth. The more plant variety the better. It has been demonstrated that pollen is necessary for proper ovarian development in some species of bees. Therefore, it may be essential for egg-laying females to find plants with high protein content.



What does this mean for us?

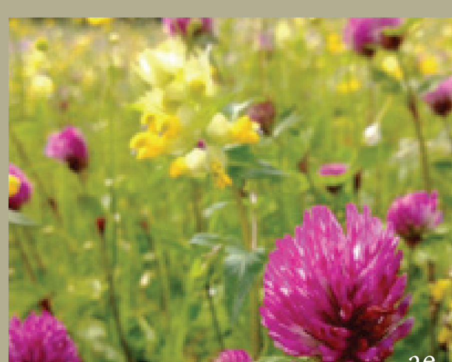
The best thing one can do to help bees is to provide a flower-rich habitat over the whole season. This can be done by introducing plants that are attractive to bees and have high protein content in their pollen, plus noting where bees forage in existing habitat and leaving these areas and plants undisturbed.

On each foraging trip, some bees forage exclusively for nectar, others for pollen, and some bees forage for both.

Plants high in protein include those in the family Fabaceae- the pea, bean, or legume family. [1]

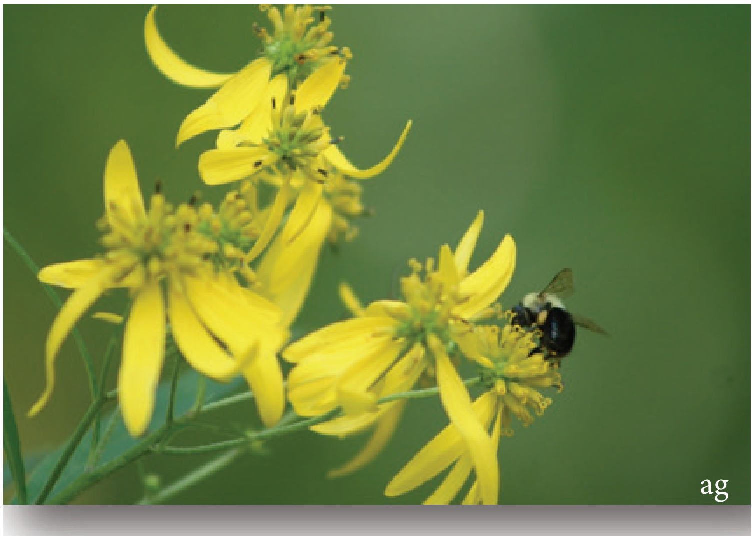
Examples of plants in Fabaceae

Bird's foot trefoil



Red clover

Wisteria



Flower Constancy

Individual bees vary in how consistent they are when choosing flowers to visit. Some foraging bees collect pollen or nectar from a variety of flower species, while others collect pollen or nectar from the same species during a foraging trip. The latter bees are called flower constant.

There are two mainstream hypotheses regarding the benefits of being flower constant. The first has to do with a theory that bees might have a limited memory capacity and therefore learning to manipulate one flower at a time might be advantageous. The other hypothesis has to do with bees using a "search image" to pick out flowers from the surrounding environment.[2]

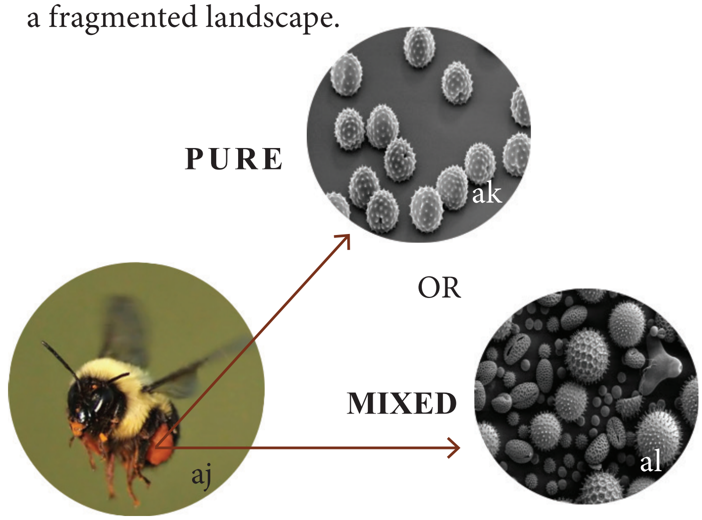
There are consequences to being flower constant. It extends foraging time, since bees are skipping over rewarding flowers in search of the species they are foraging on. On a farm, bees that are flower constant make better pollinators because they stay on the monoculture and do not clog up the stigma of the crop flowers with pollen from other plants.

Specialists and Generalists
Some species of bees inherently favor certain species of flower. Specialist species preferentially collect floral resources from select flowers (oligolectic). Generalists are less picky (polylectic). These terms apply not to the individual bee, but to the species as a whole.

Pollination
For many plant species, pollination occurs when the flowers are receptive, and pollen is moved from the male part of flowers (anthers, which produce pollen) to the female part (stigma).

Buzz pollination
Some flowers make it difficult for bees to access their pollen. For example, plants in the family Solanaceae, (such as tomatoes, potatoes, peppers, and eggplants) and Ericaceae (such as cranberry and blueberry) release pollen most efficiently through sonication. Some bees, such as bumble bees, carpenter bees, and some sweat bees, are able to do this (and are called "buzz pollinators") by contracting their flight muscles rapidly, causing the anthers to vibrate, dislodging pollen. Honey bees do not buzz pollinate, and thus, are inefficient pollinators for crops whose flowers require buzz pollination.

Forage distance
It is often the case that body size determines foraging distance, with larger bees going further than smaller ones. So for example, the large-bodied carpenter bees, bumble bees, or moderate-sized honey bees forage up to a few miles, while the much smaller sweat and mining bees may only have foraging distances of a few hundred yards. Bees with larger foraging ranges are better able to utilize patchy resources in a fragmented landscape.



Bee pollen can either be mixed or pure. Mixed pollen loads contain pollen from multiple species of plant, while pure pollen loads only contain pollen from one species.

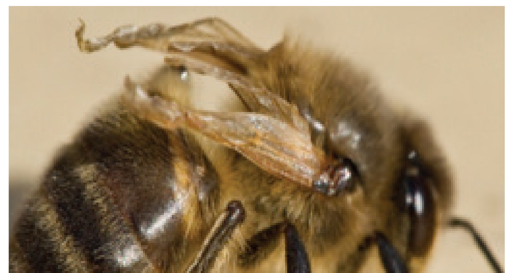
Predators

Predators of bees include robber flies, wasps, assassin bugs, spiders, lizards, and birds. However, bees do not spend much time avoiding predators. The nests of social bees are sometimes attacked by mammals like bears and skunks.


Bear attack on honey bee hives [am]

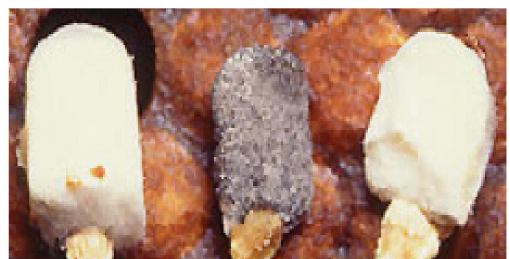
Parasites

Viruses are implicated in honey bee decline and so have received increased attention. There is evidence that honey bee viruses can spread between honey bees and bumble bees, but little is known with respect to other native bees. There are many viruses currently being studied in honey bees, including acute bee paralysis virus, deformed wing virus (DWV-see image at right), sacbrood virus, and black queen cell virus.

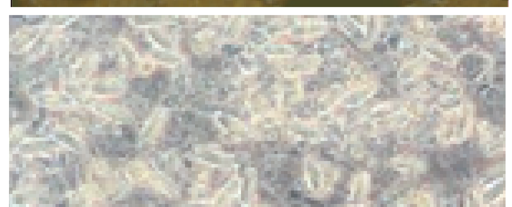

Bee infected with DWV [an]

Bacteria like those that cause American and European foulbrood in honey bees can cause substantial mortality. Bacteria are less studied in other bees.

Chalkbrood is a fungus that infests the gut of infected honey bee larvae and causes the larvae to eventually starve. Similar diseases are also found in *Megachile* and *Osmia*.

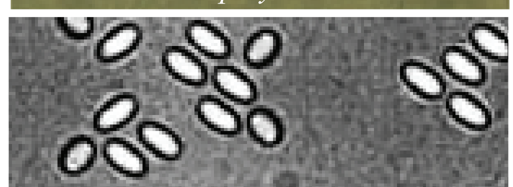

Chalkbrood [ao]

Apicystis bombi is a neogregarine (a type of protozoan) of bumble bees. The effects have been reported to be harmful, and include reduced reproductive success and queen lifespan.


Apicystis

At least three species of the microsporidian *Nosema* are known to infect bees. *Nosema apis* and *Nosema ceranae* are mostly found in honey bees and *Nosema bombi* is mostly found in bumble bees.

Nosema apis is associated with colony mortality in the winter and reduced build up in the spring. *Nosema bombi* infections often make bumble bee colonies less productive and can reduce their lifespan. It is interesting to some researchers because it is found more frequently in declining bumble bee populations than stable ones.


Nosema [aq]

Crithidia bombi is a common trypanosome of bumble bees. It can increase mortality in stressed workers. It can also induce behavioral changes that affect learning.

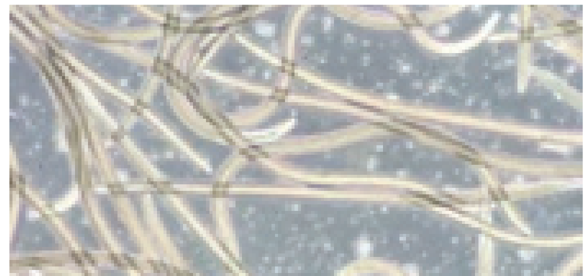

Crithidia [ap]

Parasitic mites are associated with social bees and can be ectoparasites feeding on the body or can be found in the trachea (internal breathing tubes of the bee). Some of these species include the *Varroa* mite (honey bee), *Locustacarus buchneri* (bumble bee), and *Acarapis woodi* (honey bee).

The *Varroa* mite can cause substantial loss in honey yield, shortened lifespan, and reduced sperm count in drones. It is often cited as the parasite with the most impact on the honey bee industry, likely because *Varroa* mite parasitism is positively correlated with some honey bee viruses. *Varroa* mites develop and feed on bee brood in their cells, and then they attach to adult honeybees in order to move to other bees.[3]

Nematodes are rarely found in honey bees. In bumble bees, the nematode *Sphaerularia bombi* infects overwintering queens, which die over the winter.

Varroa mite ar



Sphaerularia bombi

Parasitoids

The following parasitoids inject their eggs into adult bee hosts. The parasitoid larva completes development by feeding on the internal structures of the bee, eventually causing the bee's death.

Conopid fly (left, top) infections are fairly common and one field study in western MA showed >70% of bumble bee workers captured were parasitized.

A species of phorid fly, *Apocephalus borealis* (left, bottom), is known to infect bumble bees and honey bees. Currently, the infections are only documented in certain parts of North America.

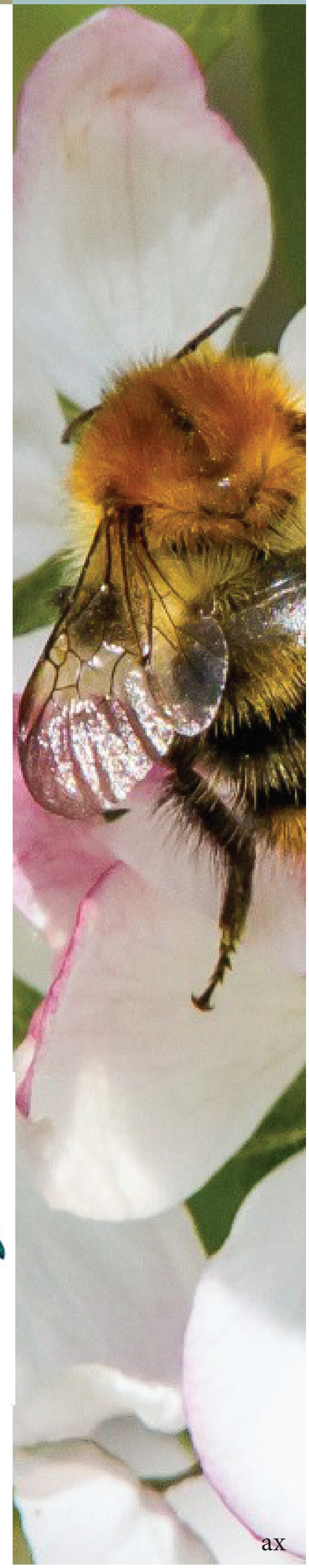
Syntretus spp. is a genus of brachonid wasp that is known to parasitize bees. For example, *Syntretus splendidus*, are parasites of bumble bees.

Terms

Parasitoid: an organsim that develops in a host's body, eventually killing it

Ectoparasites: a parasite that lives on the outside its host

Positive correlation: a relationship between two variables where, for example, if one increases, the other also increases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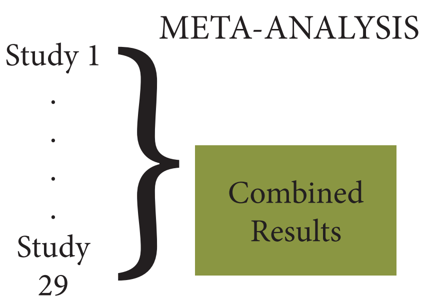
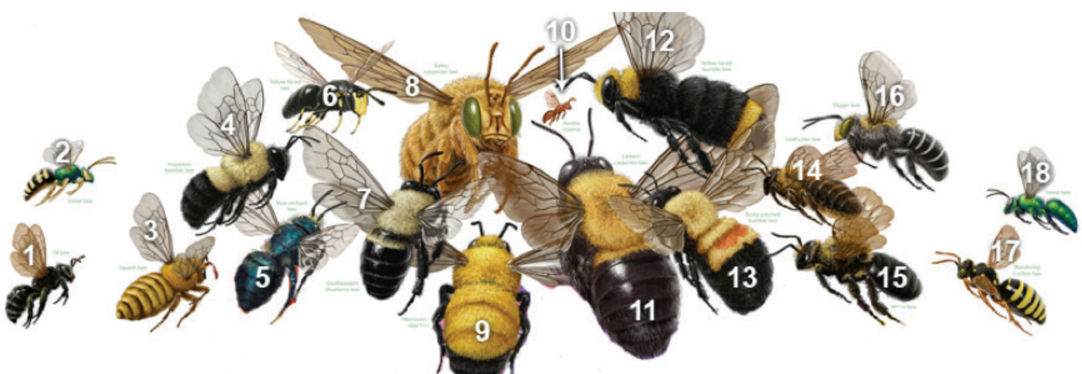
Diversity of bees is important

Bees are critical pollinators in many of our fruit and vegetable crops. In addition to managed honey bees, wild native bees may play an important role in crop pollination. Higher numbers (abundance) of wild bees may increase yield by having more bees visit, carry pollen, and pollinate flowers. More species (richness) of bees present on a crop may increase yield in several ways. It's been shown that different species of bee can affect one another's behavior while foraging. These changes can increase the effectiveness of the bee's pollination or make the species pollinate more frequently.

Also, multiple species of native bees on a crop may provide pollinators all season long since different species are active at different times of year. Richness provides essential overlap in services bees provide. This is important so that if one species is in decline at some point in time, a species with overlapping functions can still provide that service. However, although one may be able to find 100s of bee species in cranberry, blueberry, or apple fields, most species are found in small numbers. Once a farm is a large habitat of a single crop and is intensively managed, usually only a handful of different wild bee species can still be found in high numbers.



A meta-analysis is the review of findings from several studies. A meta-analysis of 29 studies conducted around the world found that fruit set increased significantly with the number of bees visiting flowers and the number of bee species present. Even when honey bees were abundant, wild bees still increased fruit set in many crops. This evidence supports the notion that wild bees are playing an important role in fruit set for many farmers.



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1. *Macropis nuda* 2. *Agapostemon texanus* 3. *Peponapis pruinosa* 4. *Bombus impatiens* 5. *Osmia lignaria* 6. *Hylaeus* sp. 7. *Habropoda laboriosa* 8. *Xylocopa varipuncta* 9. *Bombus morrisoni* 10. *Perdita minima* 11. *Xylocopa virginica* 12. *Bombus vosnessenskii* 13. *Bombus affinis* 14. *Megachile* sp. 15. *Andrena cornelli* 16. *Anthophora centriformis* 17. *Nomada* sp. 18. *Augochorella pomoniella*

Cranberry Pollination

Cranberry (*Vaccinium macrocarpon*) is a woody vine that is native to northern North America. It is a perennial plant that blooms during June and July.

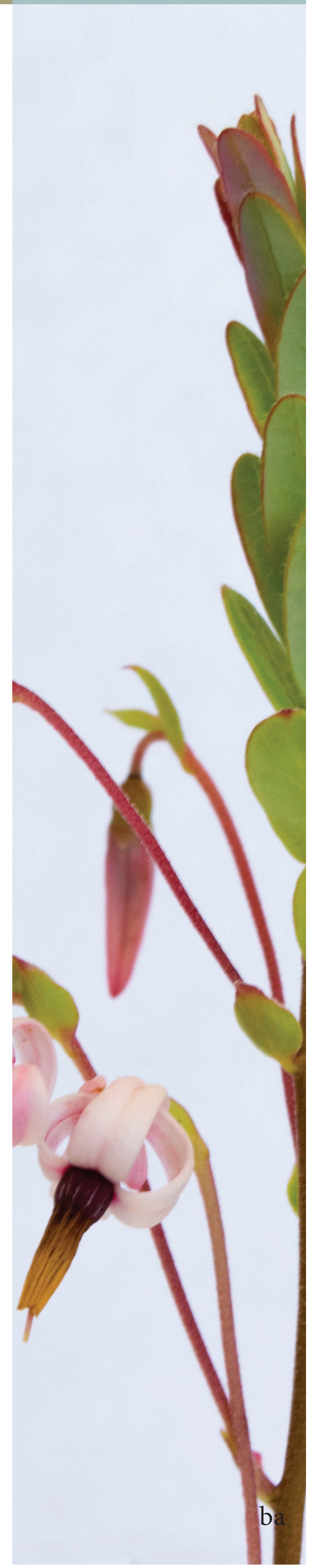
For optimal fruit set in cranberry, insect pollinators are needed. Pollinators provide cross-pollination, which is the transfer of pollen from one plant to another. Cross-pollination provided by bees can increase the size of the fruit, the number of seeds, and the consistency in the shape of the fruit. Cranberry enforces cross-pollination in a way: for each flower, the anthers release pollen before the stigma becomes receptive.

It is difficult to make recommendations about how many honey bee or bumble bee colonies cranberry growers need for supplemental pollination. Different varieties of cranberry may need more or fewer pollinators, depending on the stand and the cultivar: these will differ in the number of uprights and the number of berries that an upright can support.

Different bogs have different native pollinator populations. Native bees, almost entirely bumble bees, are more or less prevalent at certain bogs and they often provide pollination. The pollination that native bees provide can be thought of as a baseline pollination level. The higher the baseline, the fewer managed hives need to be ordered for supplemental pollination.

One might think that monocultures would improve pollination; bees in the area have no choice but to pollinate cranberry flowers. However, vast fields of a single crop are not always supportive for native bees because they need varied habitats, varied nutrition, and consistent food sources. As mentioned above, wild bees play an important role in increasing yield, regardless of how many honey bees are present.

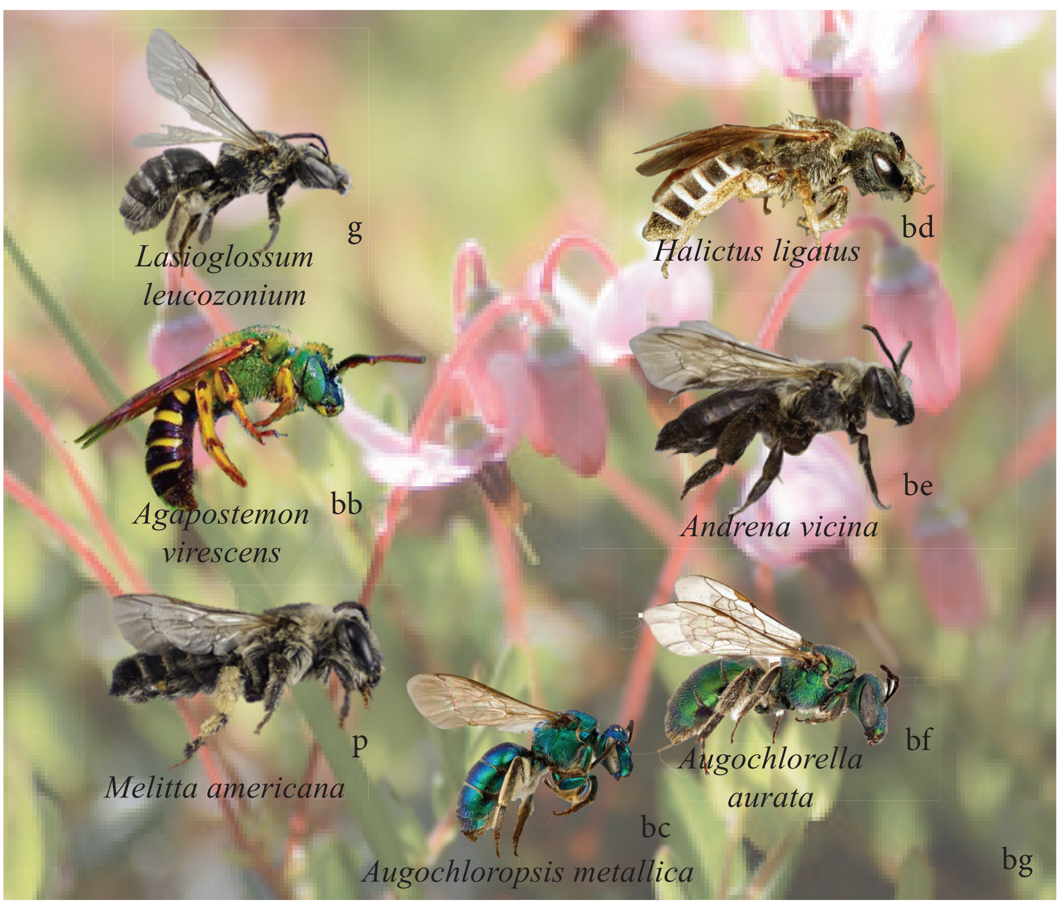
Pallets of migratory honey bee hives near a cranberry bog.

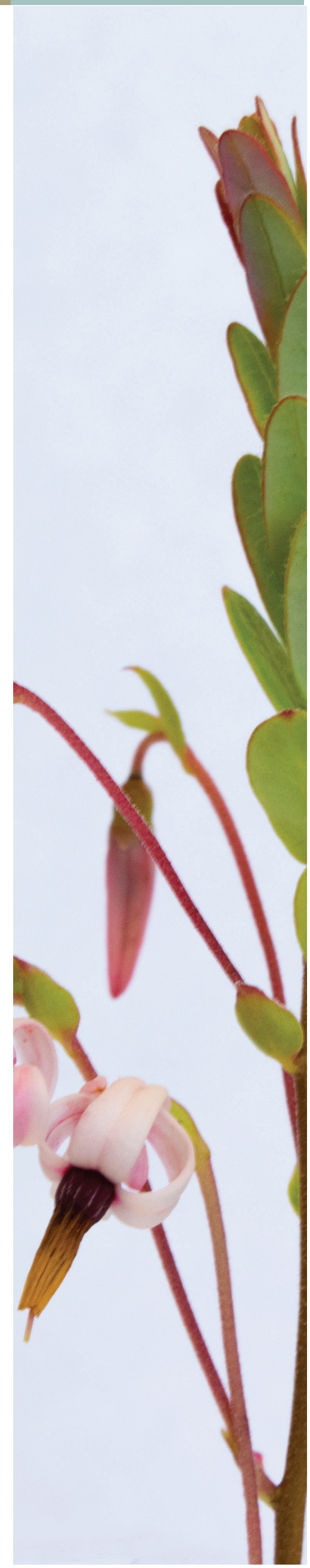


In addition to pollination, there are factors that limit the number of berries an upright can produce. Not all flowers on an upright will produce berries even with optimal pollination. Fruiting uprights can only fix enough carbohydrates to mature a subset of its flowers to marketable berries. Thus, a plant produces surplus flowers that serve as insurance in case others are lost to insects, disease, or receive insufficient pollination.

In both managed and unmanaged Massachusetts cranberry sites, bumble bees are by far the most abundant native bees; average counts (in 10-minute observation events) of a dozen workers with impressive cranberry pollen loads are typical. The most common species are *Bombus impatiens*, *B. bimaculatus* and *B. perplexus*. Twenty-five years ago, *B. vagans*, *B. affinis*, and *B. terricola* were also common in the southeast MA area, and now these three species are rare or completely absent. The most common non-*Bombus* wild bee species (including native and introduced) sampled from cranberry beds are: *Lasioglossum leucozonium, Melitta americana, Xylocopa virginica, Halictus ligatus, Halictus rubicundus, Andrena vicina, Augochlorella aurata, Agapostemon virescens,* and *Augochloropsis metallica.* With the exception of *Mellitta americana,* examination of the pollen loads of each of these species will be required to establish whether these species are using cranberry as a primary resource.

Lasioglossum leucozonium is a generalist bee that was introduced to this area and its abundance is increasing. *Mellitta americana* is a specialist and is one of the only bee species that collects pollen from only cranberry and close plant relatives. Both species are solitary and nest in the ground.





Several studies showed that bumble bees are the most active, effective, and efficient buzz-pollinators of cranberry. Bumble bees deposit more pollen on cranberry stigmas than other cranberry pollinators. Honey bees, which do not buzz pollinate and generally only gather nectar from cranberry flowers, are inefficient pollinators. This inefficiency is somewhat offset by the high numbers of foragers in honey bee colonies and the small number of pollen grains needed to set fruit. Bumble bees and other wild native bees may be particularly important if weather conditions are poor through much of cranberry bloom. Inclement weather can dramatically reduce honey bee activity, but bumble bees still forage in cool or rainy weather.

To preserve wild bee populations, cranberry growers do not apply harmful sprays during bloom, or if pest management is necessary, they use bee-safe cultural or chemical choices. Some could adjust off-bed mowing/weed management practices to support volunteer pollen and nectar sources: prior to and after cranberry bloom. Wild bees utilize many of the weedy and/or invasive alien species that can flourish in the dry, inhospitable conditions around managed beds, particularly clovers (*Trifolium* spp), *Jasione montana*, common dewberry (*Rubus flagellaris*), goldenrods (*Solidago* spp), Bird's foot trefoil (*Lotus corniculatus*), spotted knapweed (*Centaura maculosa*), catsear (*Hypochaeris radicata*), vetch (*Vicia cracca*), and beach rose (*Rosa rugosa*).

Enhancement of Pollinator Habitat

In an ideal crop ecosystem, the landscape would include an array of native plants and nesting resources that are preferred by pollinators. This is discussed later.

Commercial Bumble Bee Hives

Commercial bumble bees have been available since 1988. When commercial bumble bee hives were first produced, they were shipped all over the world without careful inspection for parasites or pathogens. Today, there are regulations in place that require producers to be more diligent about screening for diseases. Nonetheless, transportation of live animals, including bees, among locations is always a dicey activity, given the possibility of introducing either deleterious genes to an adapted local population or an undetected or virulent rogue strain of a pathogen.

bh

bi

In the Northeast, *Vaccinium corymbosum* (highbush blueberry) and *Vaccinium angustifolium* (lowbush blueberry) are common crop genotypes. Lowbush genotypes range in height from about 4-6 inches and highbush range from 6-13 ft. tall.


bj

Blueberry flowers are adapted to be optimally pollinated through buzz pollination (see page 10). Many native bees, for example in the genera *Andrena, Bombus, Augochlorella* and *Lasioglossum* are known to be buzz pollinators, and these are reported in surveys of blueberry fields. Other bees, such as *Osmia spp*., drum the anthers with their forelegs. While wild bees contribute to blueberry pollination, most growers supplement naturally-occurring populations with managed honey bees and/or bumble bees to meet the high pollination demand of millions of flowers found in large fields.

Honey bees are not well-suited to blueberry. For lowbush fields, Frank Drummond of UMaine recommends that honey bee colonies be installed at a high rate[4], because foragers are such inefficient pollinators. They do not buzz pollinate and cannot readily extract pollen from flowers. However, they do visit the fields in high numbers and feed on nectar, and in the process, move some pollen. For honey bees in highbush blueberry, Michigan State researcher Rufus Isaacs reports that blueberry flowers are unattractive and produce a low level of nectar compared to competing flowers. Here, the recommendation is to install bees near the crop after the onset of bloom, so that the honey bee foragers will learn to visit the fields and focus on the crop.


bk

Highbush blueberry

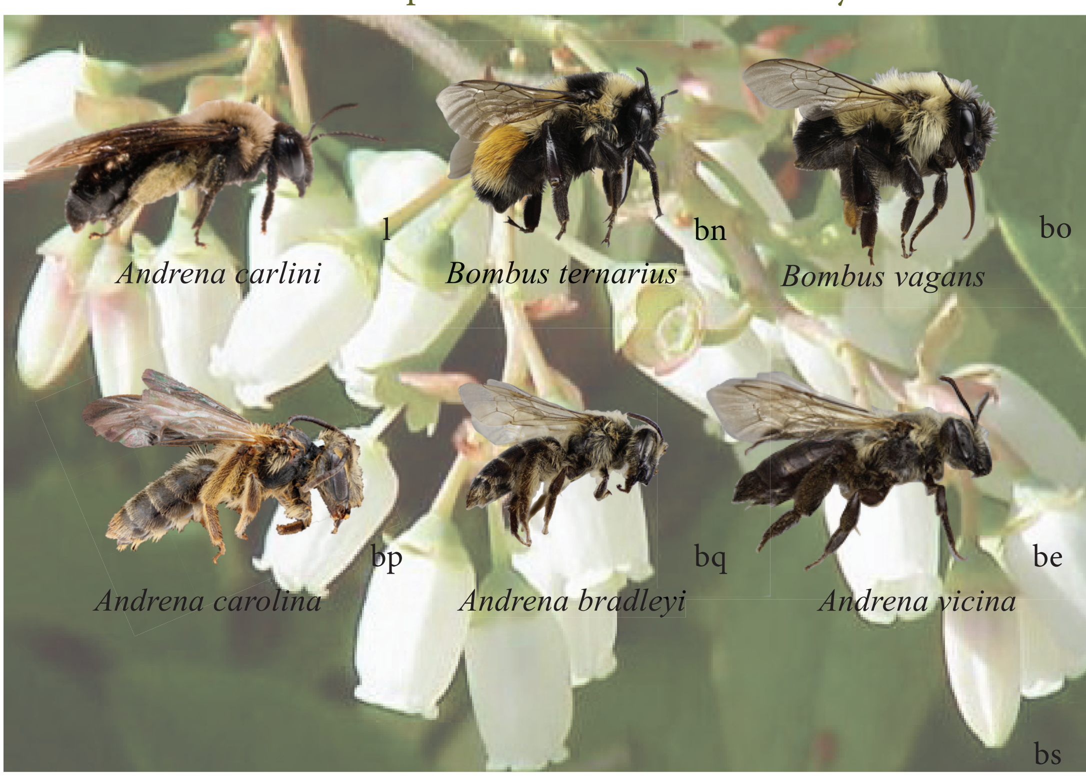
Pollination in a highbush blueberry field can be complicated. For example, for some cultivars, only pollen transferred from certain other cultivars will lead to maximized fruit size. Thus, for enhanced yield, an interplanting of compatible cultivars that bloom around the same time is required. On the other hand, some cultivars are 'self-fruitful' here, pollen exchange among the same cultivar works.

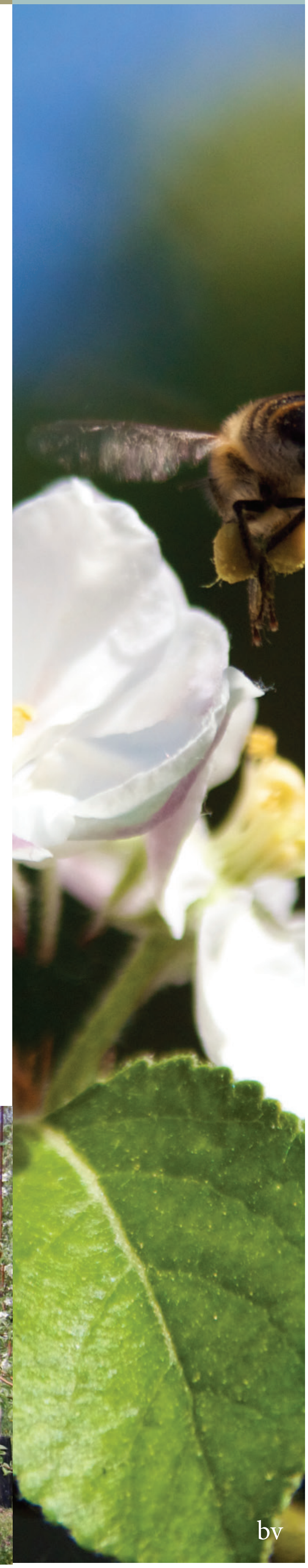
Sampling studies in NY and MI (sometimes using bee bowl traps that capture even bees that are not foraging on blueberry) have shown over 150 wild bee species in highbush blueberry fields. However, during bloom, only a dozen of these were really abundant and carrying enough pollen to be considered an important pollinator. By far the highest abundance of species was in the Halictidae (sweat bees) and in the genus *Andrena* (mining bees).

Lowbush blueberry

In Maine, (using direct capture of bees on the flower) over 125 wild bee species in fifteen genera have been documented visiting low bush blueberry. The most important bees during bloom are *Andrena* mining bees (e.g., *A. carlini*, *A. carolina*, and *A. vicina*) and queens of bumble bees (e.g., *Bombus ternarius*, *B. impatiens*, and *B. bimaculatus*). Examination of pollen loads for bees captured on bloom revealed that both *Andrena bradleyi* and *Andrena carolina* were flower constant, with close to 100% of pollen loads made up of blueberry pollen. Studies also show *Andrena* and *Bombus* to be the most effective pollinators because they deposit up to six to eight times the amount of pollen per flower visit than honey bees. Native bees, like those mentioned above, are important for the pollination of early blooming genotypes. Early bloomng genotypes tend to provide the largest yield.

Wild Bee Species on Lowbush Blueberry





Different apple cultivars bloom early, mid, and late season. All trees within a cultivar are clones of one another. Often, more and better fruit are produced when there is cross pollination between apple cultivars. Pollinators make it more likely that pollen will be moved between cultivars of apple. Growers rely on honey bees and native bees, and some growers order commercially available blue mason bees (*Osmia lignaria*).

Surveys of growers in central New York conducted by the Bryan Danforth Lab at Cornell found that the majority of large apple orchards (over 100 acres) always rent honey bees for supplemental pollination. On the other hand, most smaller apple orchards (fewer than 10 acres) never rent honey bee hives. Most apple growers viewed native bees as valuable pollinators.

In another study, multi-year sampling by the Danforth lab reported 80 species in the orchard system, and of these, the most important pollinators were mining bees, mason bees, and bumble bees, in the genera *Andrena*, *Osmia*, and *Bombus,* respectively.

The Danforth group observed that native bees often outnumber honey bees in apple orchards. Orchards with more bee diversity also had more surrounding natural areas and lower pesticide use. There was a positive correlation (a relationship where if one variable increases the other also increases) between fruit set and native bee richness and abundance. They noted several mechanisms that could account for these findings. Native bees may become especially important when weather prevents honey bees from leaving their hives. Many native bees forage in rainier, windier, and colder conditions than honey bees. They also play an important role maintaining evenness in the foraging behavior of honey bees. When native bees are present, honey bees are less likely to skip over less attractive flowers or branches on apple trees.

Pumpkin is a vine crop in the genus *Cucurbita* that is native to North America. Pumpkin grows best in warm climates with a soil temperature of at least 60° F. Pumpkin is grown around the world for food as well as ornamentation. Cucurbits are monoecious, meaning there are male and female flowers on the same plant, shown at right. The flowers open at dawn and permanently wilt within several hours. Pollinators that forage before noon are necessary for the production of marketable pumpkins.

bz

In northeastern North America the most important pumpkin pollinators are the common eastern bumble bee (*Bombus impatiens*), squash bees (*Peponapis pruinosa*), and honey bees (*Apis mellifera*). In many cases this crop does not require supplemental pollination from honey bees.

Bumble bees are considered the most effective pollinator of pumpkin. Bumble bees contact the reproductive parts of the flowers nearly every time they visit a flower, while other bees do not.

ca

The Squash Bee

The squash bee is a specialized native pollinator of pumpkin and other cucurbits. Squash bees almost exclusively collect pollen from cucurbits.

Squash bees are solitary insects that nest in the ground. Females dig tunnels and lay their eggs in cells within those tunnels. The eggs develop and overwinter as pre-pupa.

A few things make squash bees unique from other native bees. For other bees, diverse plant resources from early spring to late fall may be key; however because squash bees specialize on cucurbits, adult activity is timed to coincide when cucurbit flowers are present (a little more than two months in the summer). They emerge when cucurbits are blooming and overwinter when cucurbit flowers stop blooming. Another interesting observation is that males contribute to pollination. Male squash bees search for females on squash flowers, so when they are searching for females, they are also spreading pollen.

cb

Worldwide, certain species of bumble bees are exhibiting decline in abundance and range. (Red List of Pollinator Insects: http://www.xerces.org/pollinator-redlist/) In North America, populations of *Bombus affinis,* the rusty-patched bumble bee, have totally collapsed. However, some species of bumble bees (e.g. *Bombus impatiens* in many states) and other wild bees are increasing; researchers have suggested that generalist bee species are doing better than specialists under current conditions. Decline may be occurring as a result of several and possibly interacting stressors. This includes the following:

Habitat loss

A meta-analysis assessing threats to abundance and diversity of wild bees found that habitat loss is the most destructive human activity to wild bees. Habitat loss includes the degradation, destruction or fragmenting of habitat. Rarer bees that may specialize on endemic plant species would be highly vulnerable to the loss of native flora in degraded habitats.

Invasive species

Alien plants, animals, and pathogens may cause harm to native species of pollinators. Invasive species of plants and animals may usurp resources from native pollinators. For example, an invasive plant species may become dominant in a habitat and displace a specialist bee's preferred flowers. Invasive pathogens may harm the native pollinators directly by exploiting the lack of resistance native pollinators have.

Pathogen spillover

As commercial honey bees and bumble bees are transported, they may introduce new or different strains of pests and diseases to wild vulnerable populations. This includes parasites such as mites, microsporidia, or other fungi, protozoa, viruses, bacteria and parasitoids.

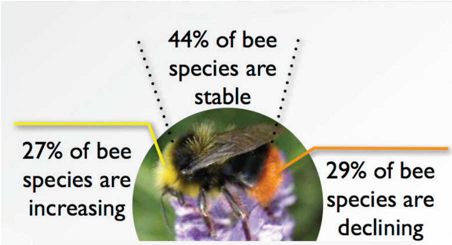
Pesticide applications

Widespread use, starting in the 1990s, of the neonicotinoid insecticides is cited as a major threat to bees. These are highly toxic to bees, are persistent in the environment, and are systemic (they move through the plant and end up in the nectar and pollen). Experiments in field and lab conditions have yielded mixed results for neonicotinoid impacts, but there is little doubt that these compounds pose a serious threat. Fungicides, which are freely applied to vast areas of blooming crops, may also be problematic.

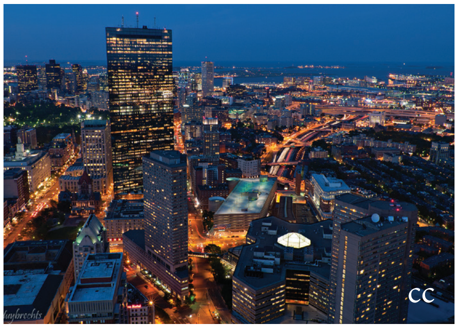
Climate Change

The Earth's climate is warming, and this could result in a lack of synchrony in the phenology of host plants and a bee's active interval. More intense storms, more frequent rain, heat, and drought could impact populations.

These factors may have more or less impact in different geographic locations. It is likely that these factors interact with each other, so it is not just habitat loss, or just invasive species, but a combination of stressors.



Bartomeus et al 2013 PNAS, In press.
Data reflects relative abundance changes in the northeastern US along the last 100 years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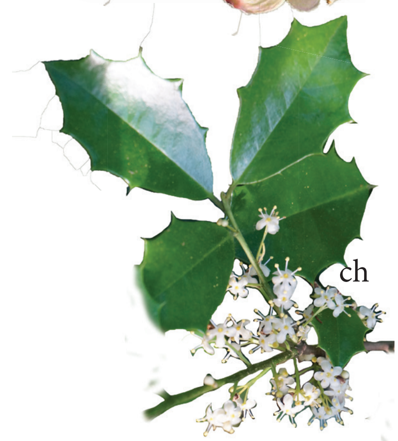
Bee habitat

In a crop ecosystem, bee habitat encompasses the bee's food and nesting resources, water, and mating sites that are required for successful completion of their life cycle. Most habitat management schemes focus on creating set-aside areas where flower richness and abundance of a site is increased, together with undisturbed habitat for nesting. Since most wild bees nest in the soil, attention to non-mulched, well-drained bare areas can be important. **For farmers.** USDA-NRCS offices can provide support for the expense of creating and maintaining habitat for bees. The Xerces Society at www.xerces.org provides extensive information on site preparation, pollinator plants and seed mixes for the US regions (see page 25).

Other ways to provide habitat and floral resources is to leave dead tree stands for cavity nesters or let naturally-occurring native plants grow. Plants with pithy/hollow stems such as staghorn sumac (*Rhus typhina*) or raspberry and blackberry (*Rubus* spp.) can provide nest sites for some bees. Many of us like manicured landscapes, but letting some areas get untidy is beneficial to wildlife.

Gardens in urban areas are not only good for us, but they are awesome for the bees! Neighborhoods with more backyard gardens have been shown to have higher bee diversity than neighborhoods with fewer backyard gardens. This demonstrates correlation, not causation, but it makes intuitive sense that more food means healthier and more abundant bees.

As you walk through an outdoor garden shop of a nursery or box store, note where bees are not foraging and where they are foraging. **Homeowners** should note that many of the common bedding plants and bushes available at markets are not preferred or not used at all by bees. Some of these widespread '**non-bee plants**' are pansy (*Viola x wittrockiana*), daylily (*Hemerocallis* spp.), hybrid tea rose, double marigold (*Tagetes* spp.), petunia, New Guinea impatiens (*Impatiens hawkeri*), begonia (*Bogonia obliqua*), peony (*Paeonia lactiflora*), forsythia (*Forsythia suspensa*), and lilac (*Syringa vulgaris*).



Plants to support bees

Some key native plants that are visited by native bees include willows (*Salix* spp.), goldenrods, (*Solidago, Euthamia*), milkweeds (*Asclepias*), summersweet (*Clethra alnifolia*), and asters (*Symphyotrichum*). Additional plantings to a bee habitat include these species as well:
Lupine (*Lupinus perennis*)
Beardtongue penstemon (*Penstemon digitalis*)
Bee balm (*Mondarda fistulosa*)
Spotted bee balm (*Mondarda punctata*)
Purple coneflower (*Echinacea pupurea*)
Partridge pea (*Chamaecrista fasciculate*)
Mountain mint (*Pycnanthemum virginianum*)
Lance-leaved coreopsis (*Coreopsis lanceolata*)
Blazing star (*Liatrus spicata*)
Joe Pye Weed (*Eutrochium purpureaum*)
Summersweet (*Clethra alnifolia*)
Blue vervain (*Verbena hustata*)

Especially for bumble bees

Based on our studies of the pollen loads carried by bumble bees, we recommend these plant species, a few may have invasive varieties or cultivars.

<u>Early season plants for queen bumble bees:</u>
Rhododendron spp.
American pussy willow (*Salix discolor*)
Dogwood (*Cornus* spp.)
American holly (*Ilex opaca*)
Black cherry (*Prunus serotina*)
Winterberry (*Ilex verticillata*)
Black willow (*Salix nigra*)
Honeysuckle (*Lonicera* spp.)
Beach plum (*Prunus maritima*)
Purple coneflower (*Echinacea purpurea*)
Common yarrow (*Achillea millefolium*)
Swamp azalea (*Rhododendron viscosum*)
Beard tongue (*Penstemon* spp.)
Southern arrowwood (*Viburnum dentatum*)
Swamp rose (*Rosa palustris*)
Lowbush blueberry (*Vaccinium angustifolium*)
Wild lupine (*Lupinus perennis*)
Crabapple (*Malus* spp.)

<u>Plants for worker bumble bees:</u>
Shrubby St. John's wort (*Hypericum prolificum*)
White meadowsweet (*Spiraea alba*)
Honeysuckle (*Lonicera* spp.)
Threadleaf coreopsis (*Coreopsis verticillata*)
Mountain laurel (*Kalmia latifolia*)
Dewberry (*Rubus* spp.)
Virginia rose (*Rosa virginiana*)
Sweet pepperbush (*Clethra alnifolia*)
Evening primrose (*Oenothera biennis*)
Wild hydrangea (*Hydrangea arborescens*)
Black-eyed Susan (*Rudbeckia hirta*)
Gayfeather (*Liatris spicata*)
Jewelweed (*Impatiens capensis*)
Joe-pyeweed (*Eutrochium purpureum*)
Heath aster (*Symphyotrichum ericoides*)
New England aster (*Symphyotrichum novae-angliae*)
White clover (*Trifolium repens*)
Red clover (*Trifolium pratense*)

Installing New Pollinator Habitat

When choosing flowers to install as part of a pollinator habitat, **native species** are often better choices. They have adapted to thrive in the local environment and have coevolved with native pollinators. When native plants are too limiting (for example in the harsh sand plain region of MA where cranberries are grown), certain introduced, non-invasive plants may be important (see following page).

Sun exposure and soil characteristics should be considered when selecting a site for a pollinator habitat. Many plants in pollinator habitats prefer full sun. Drainage, pH, salinity, and other characteristics of soil should be determined before planting. For example, rhododendrons prefer well-drained soils and acidic soils. If the site has poor drainage and low acidity, steps must be taken to correct this before planting. In this case, a raised bed and wettable sulfur is one possible solution.

Larger pollinator habitats probably attract more pollinators. When deciding where to plant within the pollinator habitat, keeping plant species clustered together, particularly in several large patches may be best.

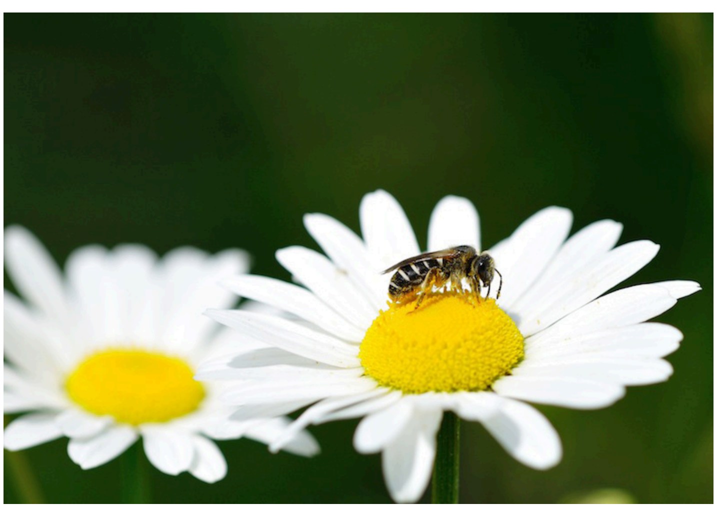
Farmers should consider **distance from their crop** when selecting a site. Some small natives only fly about 500 feet. The site should be within the foraging range of native bees, but not so close that pesticides may drift over to the planting.

Diversity is important for the success of a pollinator habitat. Different plant species provide different nutritional components that are essential for bee health. Diversity in plant species also allows for plants to bloom at different points in the season. When selecting plants, keep in mind bloom times and try to incorporate plants that bloom early season, mid season, and late season. The following link is a great resource to find when plant species are in bloom: http://www.wildflower.org/

There are two ways to install plants in pollinator habitats: **seed mixes and transplants.** Seed mixes should be purchased from local sources that harvest their seeds nearby for the highest chance that the seeds will take. Transplants are often used because they provide resources to pollinators quickly, but they are more expensive. If a transplant is not used, it may be several seasons before plants begin flowering.

Existing Habitat

Most of us like the aesthetic of manicured landscapes. However, this requires the removal of wildflowers and debris that bees utilize. Many of the plants we consider weeds (like dandelions, fall asters, goldenrods) are great resources for native bees, and patches of bare ground, as well as dead trees, wood piles and twigs are nesting habitat. Consider allowing some wildflowers and debris to remain around the landscape. For farmers, consider allowing some wildflowers to grow around the crop before and after bloom.

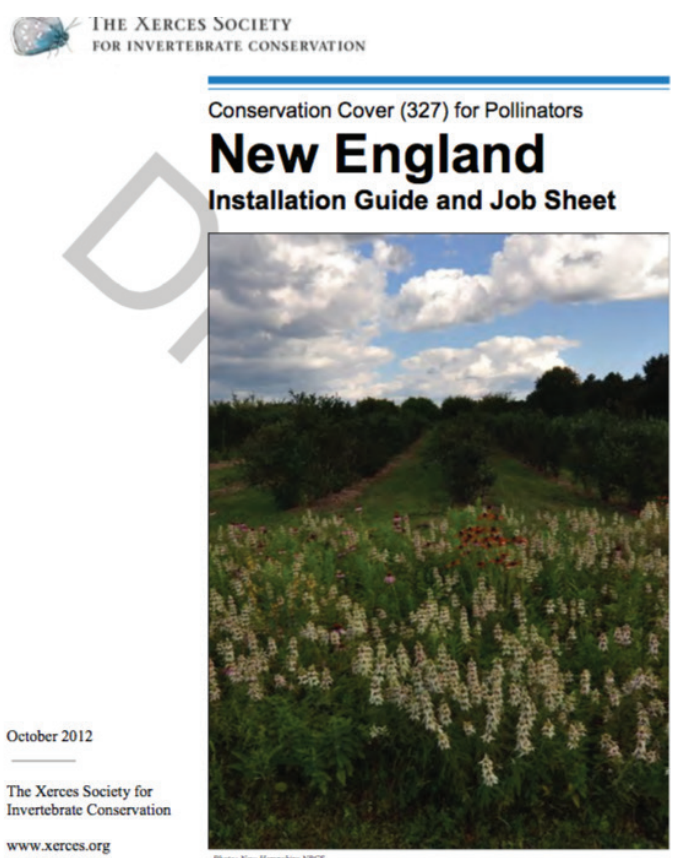


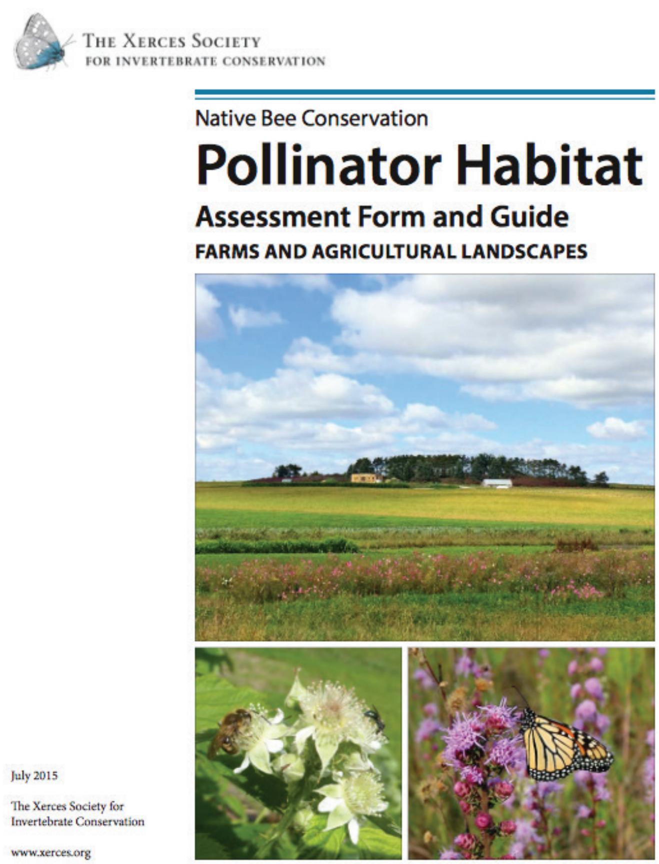
The big picture

A large proportion of bees use alien and invasive plants. It is common to see native bees foraging on spotted knapweed (*Centaurea maculosa*), autumn olive (*Elaeagnus umbellata*), Japanese knotweed (*Fallopia japonica*), Japanese honeysuckle (*Lonicera japonica*), and other invasive species. We do not recommend planting invasive species. However, must all plants in a garden be native? We think that some introduced non/native ornamental plants can attract and provide resources to bees without much harm to the environment because they are contained and do not take over natural areas. They are particularly important in tough environments or when flowers are in low abundance, such as early or late in the season. These include but are not limited to: Russian sage (*Perovskia atriplicifolia*), Japanese spirea (*Spiraea japonica*), rose of Sharon (*Hibiscus syriacus*), catmints (*Nepeta* spp.), thyme (*Thymus vulgaris*), and autumn joy (*Sedum spectabile*).

Artificial Nesting Habitat

The success rate of providing artificial nests is low and we do not recommend installing artificial nests.





Readers can go here for an in-depth guide on how to install and maintain habitat for pollinators: http://www.xerces.org/wp-content/uploads/2013/01/InstallGuideJobSheet_NewEngland_CnsrvCvr.pdf

Readers can go here for a guide on how to assess and quantify pollinator habitat for improvement: http://www.xerces.org/wp-content/uploads/2009/11/PollinatorHabitatAssessment.pdf

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Footnotes

1. You can find the protein contents of other plant families in Hanley *et al*, 2008. (Hanley, M.E., Franco, M., Pichon, S., Darvill, B. & Goulson, D. (2008). Breeding system, pollinator choice and variation in pollen quality in British herbaceous plants. *Functional Biology 22*: 592-598.) Check here for more information for Fabaceae in MA.
http://uswildflowers.com/wfquery.php?Family=Fabaceae&State=MA

2. Learn more about search image in bees (and a wealth of other things about bumble bees) by reading **Dave Goulson's** book **Bumblebees: Behaviour, Ecology, and Conservation.**

3. For a detailed summary on *Varroa* mites check here:
http://entnemdept.ufl.edu/creatures/misc/bees/varroa_mite.htm

4. According to Frank Drummond the recommendations are anywhere from 0-4 hives per acre depending on the density of native bees. However, some 'risk averse' growers will stock 8-10 hives per acre.

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