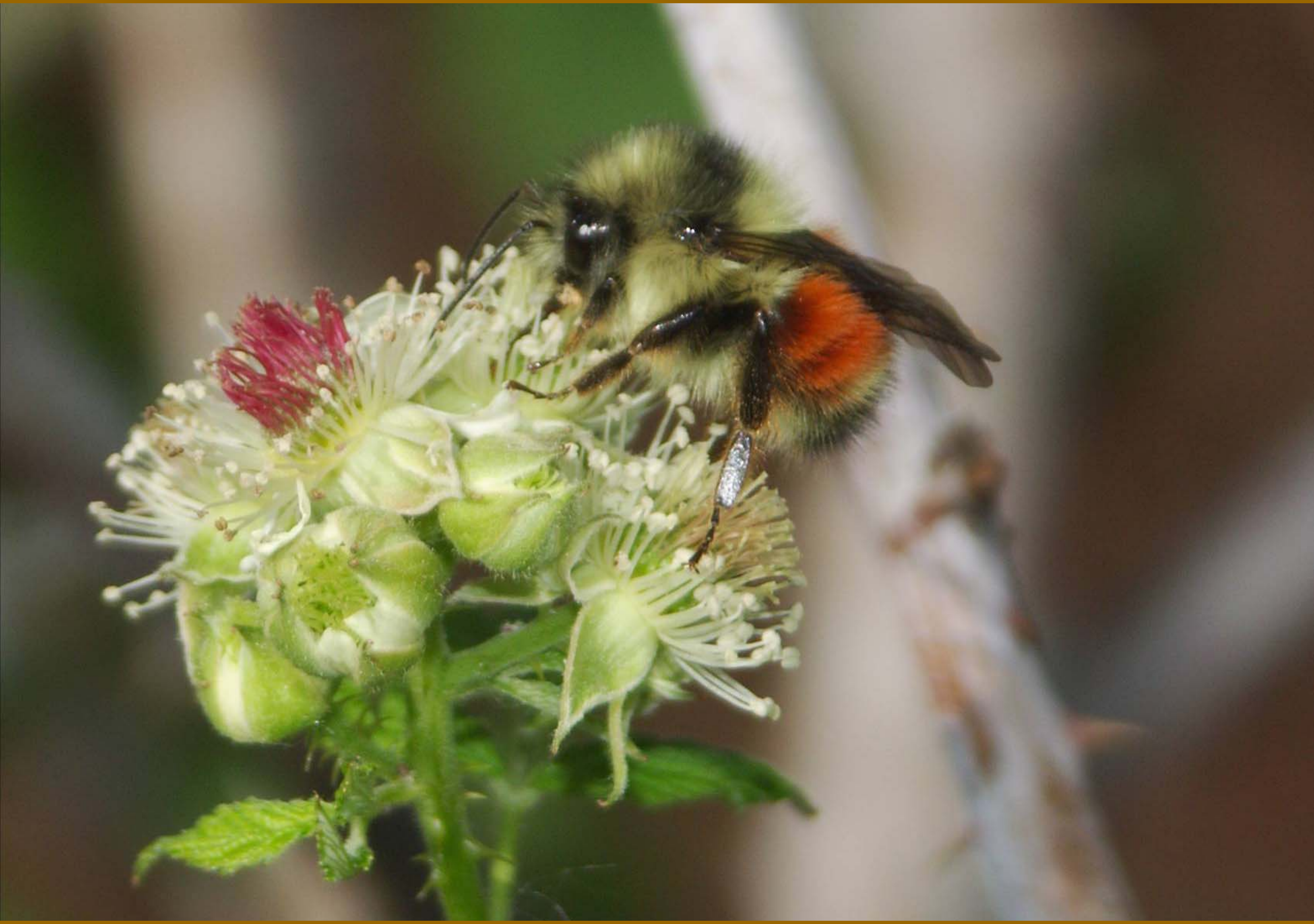
Organic Farming for Bees

Conservation of Native Crop Pollinators in Organic Farming Systems



The Xerces Society for Invertebrate Conservation

Organic Valley Family of Farms

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INVERTEBRATE CONSERVATION FACT SHEET

Farming with Pollinators

Increasing Profit and Reducing Risk

Pollinators are a critical part of profitable agriculture.

Native bees can provide all the pollination a crop needs.

Native bees are more efficient than honey bees at pollinating some crops.

Native bees can buffer against honey bee losses.

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Bumble bees are important pollinators of raspberry and other cane crops (Photograph © Mace Vaughan)

Insect pollination is critical for the production of many important crops in the United States including alfalfa, almonds, apples, blackberries, blueberries, canola, cherries, cranberries, pears, plums, squash, sunflowers, tomatoes, and watermelons. Native pollinators, most importantly wild bees, provide free pollination services and enhance farm productivity and profitability through increased yields and improvements in crop quality. Native pollinators supplement services provided by managed pollinators and are an increasingly important resource in 21st century agriculture.

Native Pollinators Can Increase Crop Yields

There are approximately 4,000 species of native bees in North America, and—if adequate natural habitat is nearby—they can provide much of the pollination necessary for many crops, and in some cases all of it. For example:

- Over fifty species of native bees visit watermelon, sunflower, or tomato crops in California.
- Over eighty species of bees pollinate berry crops in Maine and Massachusetts.
- Native pollinators have been shown to nearly triple the production of cherry tomatoes in California.
- Wild native bees improve the pollination efficiency of honey bees in hybrid sunflower seed crops by causing the honey bees to move between male and female rows more often. The only fields that had 100 percent seed set were those with both abundant native bees and honey bees.
- If more than 30 percent of the area within 1.2 km of a field is natural habitat, native bees can deliver full pollination of watermelons in California's Central Valley.
- In the absence of rented honey bees, canola growers in Alberta, Canada, make more money from their fields if 30 percent of the land is left in natural habitat, rather than planting it all. This natural habitat supports populations of native bees close to fields and increases bee visits and seed set in adjacent crops.


Photograph by USDA-ARS/Keith Weller


Photograph by USDA-ARS/Scott Bauer


Photograph by USDA-ARS/Scott Bauer

Native Bees Are Effective and Efficient Pollinators

Native bees are more effective than honey bees at pollinating flowers on a bee-per-bee basis.

- Only 250 female orchard mason bees (also called blue orchard bees) are required to effectively pollinate an acre of apples, a task that would need 1.5 to 2 honey bee hives—approximately 15,000 to 20,000 bees.
- Many native bees, such as mason and bumble bees, will forage in colder and wetter conditions than honey bees.
- The range of foraging behaviors is more diverse among many species of native bees than in European honey bees. For example, honey bees foraging for nectar seldom contact the anthers (pollen-producing structure) in many orchard crops, unlike orchard mason bees that forage for both pollen and nectar.
- Some native bees specialize in one type of flower. Squash bees, for example, visit primarily cucurbits; the females begin foraging before dawn, and males spend the night in the flowers, resulting in efficient pollination and larger fruits.
- Unlike honey bees, bumble bees and other native bees perform buzz pollination (the bee grabs onto a flower's stamens and vibrates its flight muscles, releasing a burst of pollen from deep pores in the anther). This behavior is highly beneficial for the cross-pollination of tomatoes, peppers, cranberries, and blueberries, among other plants. Although tomatoes don't require a pollinator to set fruit, buzz pollination by bees results in larger and more abundant fruit.

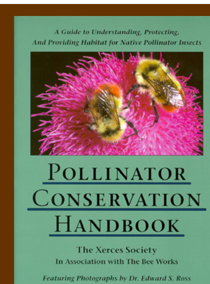
Native Bees Can Buffer Against Pollinator Losses

If populations of one bee species decline because of natural cycles of parasites or disease, other native bee species can fill the gap and provide a stable, reliable source of pollination. Furthermore, if the beekeeping industry continues to have trouble because of pests and diseases, or the mysterious Colony Collapse Disorder, native bees can fill in when honey bees are in short supply or more expensive. Farms with strong populations of native pollinators may save money because they have less need for imported hives of honey bees

Native Pollinators Can Help Diversify the Farm

- Farms that provide habitat for native bees may promote themselves as wildlife-friendly or sustainable. When faced with many choices about where and from whom to purchase produce, consumers may choose farms that are "pollinator friendly" over others.
- If a small farm is open to tours or u-pick—an increasing trend, especially at berry patches—beautiful hedgerows and other improvements for wildlife can be promoted as an additional reason to visit the farm. A farm could even host a tour showcasing its resident, beneficial insects.
- Some species of wood-nesting bees may be reared in nest tubes and sold at local farmers markets or produce stands for home gardeners looking for efficient, local, and gentle (non-stinging) pollinators.

The Xerces Society has been a leader in pollinator conservation for more than a decade. For more information about how to conserve pollinator habitat on farms, read *Farming for Bees* and the *Pollinator Conservation Handbook*. These and other educational resources can be found on our website, www.xerces.org.



Organic Farming Practices

Reducing Harm to Pollinators from Farming

Organic agriculture offers many benefits to pollinators.

Despite this, some common organic farming practices can harm these valuable insects.

An awareness of the needs of native bees will help farmers balance production practices with efforts to conserve this vital resource.

Written by
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An essential activity on farms, tillage can impact beneficial insect populations. *Photograph by USDA-ARS/Keith Weller*

The reduced use of pesticides, as well as more sustainable management practices makes organic farms important partners in pollinator conservation efforts. Despite this, some practices that are used by organic growers can be detrimental to pollinators.

For example, in the absence of readily available conventional herbicides, many organic growers depend heavily on tillage as a primary weed control strategy. Since approximately 70 percent of our native bees nest underground, increased tillage may be detrimental on farms where these insects are needed for pollination.

This fact sheet provides an overview of how common organic farming practices might affect pollinators. It may not be possible to incorporate all of the recommendations outlined here in particular cropping systems, especially when other priorities such as weed control and pest management need to be considered. Where particular recommendations can be followed however, growers are likely to benefit from improved pollination services, a reduced need for rental honey bees, and greater farm biodiversity.

For information on the effects of organic-approved pesticides on pollinators, see the companion fact sheet, *Organic-Approved Pesticides. Minimizing Risks to Pollinators.*

NATIVE BEE DIVERSITY

North America is home to approximately 4,000 species of native bees. These insects provide pollination services for many crops, and have been estimated to contribute $3 billion annually to America's agricultural economy. In California alone, more than sixty native bee species have been documented as important pollinators of tomato, watermelon, and sunflower. In the northeastern U.S., more than eighty species have been observed pollinating various berry crops.

While the non-native, European honey bee (*Apis mellifera*) is the most important managed crop pollinator, its numbers are in decline in the U.S. because of disease and other factors. This makes the role of native bees more important than ever. Native bees may also be preferred by some organic farmers who

Impact of Common Organic Farming Practices On Pollinators

The following table summarizes some of the known interactions between bees and common organic farm practices. Please note that this is not an exhaustive list. For more information on each practice, see the Notes on Farm Practices that follows.

Farm Practices	Beneficial	Neutral	Detrimental
Weed Control Practices			
Primary Tillage			■
Secondary Tillage		■	
Flame Weeding			■
Hand Weeding		■	
Plastic Mulch			■
Straw/Wood Mulch		■	
Cultural Management of Pests			
Floating Row Covers		■	
Fruit Bagging		■	
Classical Biological Control			■
Conservation Biological Control	■		
Crop Rotation		■	
Crop Diversity	■		
Trap Crops		■	
Sanitation		■	
Resistant Varieties		■	
Sticky Traps		■	
Pheromone Traps/Mating Disruption		■	
Other Management Practices			
Cover Crops		■	
Haying		■	

N.B. For information on chemical methods of pest control see the companion fact sheet, *Organic Farming for Bees: Reducing Harm from Organic-Approved Pesticides*.

need a dependable source of pollination but are wary of the chemical inputs (such as antibiotics and miticides) which are often used to maintain managed honey bees.

Many organic farms already have healthy populations of native bees. In some cases, these wild insects can effectively provide all necessary crop pollination services when enough habitat is available and bee-friendly management practices are implemented. As an additional benefit, many of the same practices that protect pollinators also protect other beneficial insects that may help manage pests.

Notes on Farming Practices

Weed Control Practices

Primary Tillage: Primary tillage is an essential first step in most cropping systems, and cannot be avoided. Since most (roughly 70 percent) of native bees nest underground, it is also unfortunately a practice that is detrimental to both actively nesting, and dormant or developing bee larvae. Consider using no-till seed bed preparation where possible, and consider leaving areas fallow where large numbers of ground nesting bees are concentrated. Often these will be sandy areas with poor cropping potential anyway. An example is the large concentrations of alkali bees found in some western states.

Secondary Tillage: In the absence of conventional herbicides, many organic growers are dependent on secondary tillage as their main weed control strategy. As with primary tillage, this can be detrimental to ground-nesting bee populations. Deep running secondary tillage implements (more than ~3 inches) such as heavy spring-tooth harrows are more disruptive to underground nesting bees than light surface disking, basket weeding, and raking.

Flame Weeding: No research has been performed on the effect of flame weeding on ground nesting bees. However, even if active nesting is temporarily disrupted, underground nests containing dormant or developing bees are unlikely to be affected.

Hand Weeding: Hand-weeding, performed either manually or from a lay-down work cart tractor, is unlikely to significantly affect pollinator populations.

Plastic Mulch: Ground nesting bees may be adversely affected by the widespread use of plastic mulch, both by limiting access to potential nest sites, and by inhibiting emergence of underground bees. These issues may be especially relevant in cucurbit production where specialist ground nesting bees are important, and plastic is widely used. If plastic mulch is used, photodegradable and biodegradable products are greatly preferred to limit the potential long-term impact to scrap sections buried in the field.

Straw/Wood Mulch: As with plastic mulch, straw or wood mulch may limit soil access for ground nesting bees. However, emergence by dormant underground bees should still be possible. In addition, thick layers of organic mulch may provide nest sites for bumble bees, or even potential hibernation sites for overwintering bumble bee queens.

Physical barriers such as plastic mulch or row covers offer control of weeds or insects. However, smothering the ground may prevent nesting by ground nesting bees and covers can hinder predation of pests by beneficial insects. Photograph by Eric Mader.

Cultural Management of Pests

Floating Row Covers: Fabric row covers may be an effective alternative to pesticides for some situations, and can be used as a season extending device. One potential downside is that these covers can trap emerging ground-nesting bees, and can prevent bees from accessing flowering crops. A potential solution is to periodically monitor and release trapped bees, and to temporarily discontinue use when crops are in bloom.

Fruit Bagging: Specially designed cloth bags with wire closures are widely used in Asia for apple and pear production. These devices are an extremely effective pest barrier, and are becoming more widely available in the U.S. Attaching these bags is a very time consuming process (and may be most appropriate for small operations), but it becomes easier with practice and can be incorporated into existing hand-thinning duties. The use of these bags can significantly reduce the need for pollinator-harming pesticides, while producing extremely high-quality fruit.

Classical Biological Control: The traditional approach to biological control has been to rear and release predators or pathogens of pest insects. These are typically introduced species because the pests are usually themselves non-native. Examples include the multi-colored Asian lady beetle to control aphids, various parasitic wasps and nematodes to control caterpillars and beetles, and diseases like codling moth granulosis virus, milky spore powder (for Japanese beetles), *Beauveria bassiana* (an insect-attacking fungus), and *Nosema locustae* (a disease-causing parasite of grasshoppers). This strategy has the potential for large-scale disruption of ecosystems by displacing existing native beneficial insects and killing non-target organisms. Once released into the environment these predators and pathogens cannot be re-captured. A better option may be to encourage existing populations of beneficial organisms. Furthermore, some products, such as *Beauveria*, do attack bees.

Conservation Biological Control: Instead of releasing beneficial insects, this approach provides habitat to boost populations of resident predatory insects. Examples include the planting of small-flowered or umbelliferous plants (for example, dill, caraway, Queen Anne's lace) for *Trichogramma* wasps and syrphid flies. Similarly, the creation of beetle banks (mounded piles of soil planted with bunch grasses) may encourage predatory ground beetle populations. These efforts may reduce the need for pesticides, and provide additional food and nest habitat for bees.

Crop Rotation: Alternating cropping systems can rapidly eliminate pest insect populations. For example, the Colorado potato beetle attacks solanaceous crops like potatoes, eggplants, and tomatoes; beetle numbers can be drastically reduced by rotating wheat with these crops. However, to maintain consistent pollinator populations within this changing farmscape, some kind of bee-friendly flowering crop or flowering cover crop should be grown each season.

Crop Diversity: Multiple crop species in close proximity, especially flowering bee-pollinated crops, provides more abundant forage opportunities for pollinators throughout the season. Diverse cropping systems also encourage beneficial insect predators, and limit available food sources for pest insects. Such systems can also include livestock. For example, sheep or hog grazing below apple trees reduces windfall fruit that harbors over-wintering apple maggots, and reduces the need for pesticides.

Trap Crops: Some growers intentionally place plants that are highly attractive to pest insects adjacent to less attractive crops to draw pests away. An example is eggplant planted as a trap crop near tomatoes and peppers, or serviceberry maintained as a plum curculio weevil trap crop near apples. In many cases, growers then apply insecticides to the trap crop to control pest populations. If this strategy is used, avoid spraying trap plants that are in bloom, and apply insecticides in the late evening when pollinators and predatory insects may be less active.

Conservation biological control focuses on ensuring there is adequate habitat to support populations of predatory insects, such as this syrphid fly. Syrphid flies eat aphids bot as adults and larvae. Photograph by Mace Vaughan.

Cover crops offer several benefits: they build soil fertility and tilth, disrupt pest populations when used in rotation, and they can provide an alternative source of forage for pollinators. Red clover cover crop photographed by Toby Alexander, USDA-NRCS.

Sanitation: Removal and disposal of crop residue at the end of the season can reduce pest populations, and thus reduce the need for pesticides. Sanitation can include the removal of nearby alternate host plants for crop pests. Excessively clean landscapes on the other hand may remove potential nest sites (such as hollow stems) for solitary bees. Where possible, aim for a balance between clean fields and adjacent natural habitat.

Resistant Varieties: Crop varieties that are unpalatable to pest insects can be used as a way to reduce the need for pesticides, and thus benefit pollinator and beneficial insect populations.

Sticky Traps: Various trap types are available for different pests and crop systems: yellow sticky cards and tape can be used to capture aphids and leafhoppers in both greenhouse and field settings, red sticky globes can be used in orchards to capture fruit flies, and blue sticky cards are used to capture thrips. Alone these types of traps may not be completely effective, but they can contribute to pest control efforts. Blue and yellow traps however may also attract and kill bees, and it may be useful to minimize their use if large numbers of bees appear to be captured. Adhesive pastes are also available to apply to the base of trees and vines, preventing crawling insects from ascending trunks. These are typically safe for pollinators.

Pheromone Traps/Mating Disruption: These chemical products work by mimicking the mating pheromones of pest insects, attracting them to traps where they drown or are captured on a sticky card. They are generally very safe to bees, but used alone they may not be sufficient to control all pests. Pheromone traps are available for codling moth, cabbage looper, tomato fruitworm, corn earworm, cucumber beetle, oriental fruit worm, cutworm, and peach twig borer.

OTHER MANAGEMENT PRACTICES

Cover Crops: While they are typically used to build soil tilth and fertility, flowering cover crops (buckwheat, clover, alfalfa, borage, mustard) can also provide alternative forage for bees. Grass cover crops on the other hand (such as oats or sorghum) do not provide nectar or pollen for bees. When used in rotation between other crops, cover cropping can disrupt pest populations reducing the need for pesticides.

Haying: To maintain high protein content, alfalfa and clover hay are often cut prior to 10 percent bloom. If it is possible to allow part of the hay to remain uncut, it can provide additional forage for resident pollinators.

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INVERTEBRATE CONSERVATION FACT SHEET

Organic-Approved Pesticides

Minimizing Risks to Pollinators

While organic farming offers significant environmental benefits, even some organic-approved pesticides can cause harm to pollinators.

By selecting the least toxic options and applying them when pollinators are not present, harm can be minimized.

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Productive cropping systems do not have to rely on chemical inputs for pest control. *Photograph by Matthew Shepherd*

Approximately four thousand species of bees are native to the United States. These wild insects provide crop pollination services, and are often specialized for foraging on particular flowers, such as tomatoes, squash, berries, orchard, or forage crops. This specialization results in efficient pollination, high yields, and larger fruit.

While the non-native European honey bee (*Apis mellifera*) is the most important managed crop pollinator, its numbers are in decline because of disease and other factors. This makes native bees, which contribute an estimated $3 billion worth of crop pollination annually to the U.S. economy, more important than ever. Native bees are of particular importance to organic farming because unlike honey bees, their populations can be supported without the use of antibiotics and other chemical inputs.

The reduced use of pesticides, as well as more sustainable management practices, makes organic farms an important asset in protecting our national pollinator resources. Many organic operations already have good numbers of wild bees. In some cases, these native bees can effectively provide all necessary crop pollination services when adequate habitat is available and bee-friendly management practices are implemented.

Unfortunately, however, even pesticides approved for organic agriculture can cause significant harm to bees. This fact sheet provides a brief overview of how to select and apply pesticides for organic farm operations while minimizing pollinator mortality. Keep in mind that the same practices outlined here that help protect pollinators also may protect beneficial insects such as parasitoid wasps, predacious flies and beetles, ambush and assassin bugs, lacewings, and others. The presence of these insects can further reduce pest pressure and the need for chemical treatments.


USDA-ARS/Scott Bauer


Stephen L. Buchmann

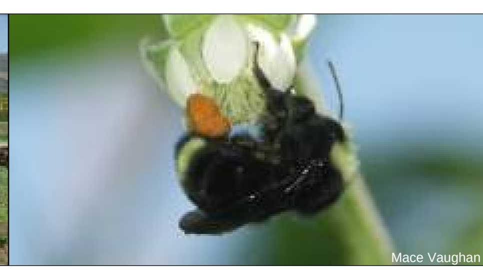

USDA-ARS/Scott Bauer

Toxicity of Common Organic-Approved Pesticides To Pollinators

The following table summarizes some of the known interactions between bees and pesticides. Please note that this is not an exhaustive list. Additional pesticides approved for use in organic agriculture may have adverse effects on bees depending on factors such as method of application (e.g., time of day) and persistence. Also, recent laboratory studies suggest that compounds such as fungicides and surfactants may be causing bee mortality in the field and merit further study. In a few cases, not all sources agree on a product's level of toxicity to bees. Where discrepancies occurred, results were ranked according to the highest potential toxicity. For more information on each pesticide, see Notes on Pesticides section that follows.

Pesticide	Non-Toxic	Low Toxicity	Highly Toxic
Insecticides/Repellants/Pest Barriers			
Bacillus thuringiensis (Bt)	X		
Beauveria bassiana			X
Cydia pomonella granulosis	X		
Diatomaceous Earth			X
Garlic	X		
Insecticidal Soap			X
Kaolin Clay	X		
Neem		X	
Horticultural Oil			X
Pyrethrins			X
Rotenone			X
Sabadilla			X
Spinosad			X
Herbicides/Plant Growth Regulators/Adjuvants			
Adjuvants		X	
Corn Gluten	X		
Gibberellic Acid	X		
Horticultural Vinegar		X	
Fungicides			
Copper		X	
Copper Sulfate			X
Lime Sulfur	X		
Sulfur			X


Mace Vaughan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Matthew Shepherd

Effects of Pesticides on Bees

Bees are poisoned by insecticides when they absorb toxins through their exoskeleton, drink tainted nectar (or in the case of honey bees, contaminated water), or when insecticidal dusts become trapped in their pollen-collecting hairs.

These poisonings may occur directly in the field when pesticides are applied. However, mortality can occur hours after the application where toxic residues still persist. Poisonings may also disproportionably affect smaller native bees. Unfortunately, most label guidelines only reflect toxicity to honey bees, even though smaller bees often require correspondingly smaller doses of insecticides before harm occurs. Another point worth remembering is that while honey bee hives can be moved or covered before pesticides are applied, the scattered populations of wild bees cannot be similarly protected.

In addition to directly killing adult bees, insecticides may be carried back to the nest in contaminated pollen or nectar and fed to developing brood. Similarly, leafcutter and mason bees gather leaf pieces or flower petals to construct brood cells within their nests. Where this brood food or vegetation is contaminated, larval mortality may occur.

Finally, rather than directly killing bees, some insecticides have detrimental sub-lethal effects. These can include disorientation, disruption of movement, reduced reproduction, and paralysis.

Safer Pesticide Applications

The first step in reducing harm to pollinators when applying pesticides is to choose the least toxic option available. In addition to product selection, however, application method and timing can have a significant impact.

The best application method is the one that keeps the pesticide on target. Drift, the movement of spray droplets to adjacent non-target areas, can be minimized by properly calibrated equipment, large droplet size, low sprayer pressure, nozzles adjusted as close to the crop canopy as possible, and spraying during appropriate weather conditions.

The best application times are when crops (or immediately adjacent weeds and cover crops) are not in bloom. Where insecticides must be applied near blooming plants, select the product with the lowest residual toxicity and spray during the late evening when bees are not actively foraging. Keep in mind that pesticide residues may persist longer on wet foliage, so dewy conditions should be avoided. For more information on applying pesticides safely, see *Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms* (see References for details).

Spray drift can be a significant threat to bees and other pollinators foraging in habitats near crop fields. Correct nozzle calibration is one way to reduce drift and maintain accurate application of pesticide sprays. Photograph from USDA-ARS.

Notes on Pesticides

Insecticides/Repellents/Pest Barriers

***Bacillus thuringiensis* (Bt)**: Bt is a naturally occurring soil-dwelling bacterium that acts as a stomach poison against certain groups of insects (moths, butterflies, flies, and beetles). It is generally considered to be a bee-safe pesticide, with no persistence (Riedl et al. 2006).

Beauveria bassiana: This naturally occurring insect pathogenic fungus has been reported to be extremely virulent to alfalfa leafcutter bees, resulting in >87% mortality after 10 days. It likely has potential to harm all bees, and should be avoided as a pest control option where pollinators are present (EPA 1999).

Cydia pomonella granulosis: Granulosis virus is intended to control codling moths (a pest of various fruit trees) and has been reported as safe for honey bees (Riedl et al. 2006). Threats are likely minimal to other bees as well.

Diatomaceous Earth (DE): DE is a naturally occurring chalk-like rock, that when crushed into a fine powder, readily absorbs lipids from the waxy outer-layer of insect exoskeletons causing them to dehydrate and die. It is a universal insecticide with the potential to kill not only pest species, but beneficial species such as bees as well. Care should be taken to not apply DE to flowering plants (Safe Solutions, Inc. 2007). Applications made during late evening, night, or early morning may result in less exposure by bees (Riedl et al. 2006). As a powder, DE may have the potential to become trapped in the pollen collecting hairs of

Crop scouting reduces pesticide applications. Treatments are only made when threshold levels are met. Photograph by Eric Mader.

bees and consequently be brought back to the nest resulting in larval as well as adult mortality.

Garlic: This insect repellent (sold as a pungent extract) can be applied at any time with reasonable safety to bees (Riedl et al. 2006). Anecdotal concerns exist about the potential for garlic to mask floral aromas and result in lower bee visitation.

Insecticidal Soap: Potassium fatty acid soaps only work when directly applied to pest insects. The soap disrupts cell membrane permeability, causing cell contents to leak, leading to death. Mortality may occur if directly applied to foraging bees, however no residual toxicity exists. Apply only to non-blooming crops, or apply at night, or when bees are not present. Where managed pollinators are maintained, hive entrances should be closed (Koppert Biological Systems 2007).

Kaolin Clay: This pest barrier consists of finely ground kaolin particles, mixed into a liquid slurry which is then sprayed onto fruits and vegetables. The resulting dry particulate film discourages insect feeding. It can be applied at any time with reasonable safety to bees (Riedl et al. 2006).

Neem: Neem is a botanical extract from the tropical tree *Azadirachta indica*. The active ingredient, azadirachtin, disrupts the hormonal system of immature insects preventing maturation. Direct contact has resulted in no observable effect on worker honey bees at concentrations well in excess of normal field application rates, and little effect on parasitic wasps. To ensure minimal contact with adult bees (that can potentially bring neem back to the nest, thus harming larvae) only apply during late evening, night, or early morning (Riedl et al. 2006).

Horticultural Oil: Horticultural oils, consisting of lightweight petroleum or vegetable oils are used to smother pest insects and are only harmful on contact (Applied Bionomics, Ltd 2006). These products should be applied only during late evening, night, early morning, or as a dormant treatment (Riedl et al. 2006).

Pyrethrins: These products are a fast-acting derivative from the pyrethrum (*Chrysanthemum cinerariifolium*) plant, and act as a broad-spectrum poison. Pyrethin is highly toxic, with as little as 0.02 micrograms sufficient to kill a bee (Cox 2002, Pesticide Information Project 1994a). Pyrethrins may be harmful for up to seven days (Applied Bionomics, Ltd 2006).

Rotenone: This dust is derived from the roots of a tropical legume and is very broad spectrum, disrupting cellular processes by inhibiting oxygen uptake. Various sources report residual effects of rotenone persisting anywhere from two hours to 42 days after application. Rotenone is extremely harmful and not compatible with bees. Where managed pollinators are present, hives should be covered or removed prior to application, and applications should be made only during late evening, night, or early morning when pollinators are not present (Applied Bio-nomics, Ltd 2006, Koppert Biological Systems 2007, Riedl et al. 2006).

Sabadilla: Sabadilla is a broad-spectrum powder or spray derived from the seeds of the sabadilla lily (*Schoenocaulon officinale*), which acts as a stomach and nerve poison. It is toxic to many insects including bees and other beneficials. Residual field toxicities lasting at least 24 hours have been reported (Klass and Eames-Sheavly 1993). Its use should be minimized wherever pollinators are present.

Spinosad: A nerve and stomach poison derived from the bacterium *Saccharopolyspora spinosa*, this product is highly toxic to bees (EPA 1997, NOSB 2002). After spray residues have dried, it may be much less toxic (Bret et al. 1997). Its use where bees are present should be avoided. If it must be used, apply only during late evening (Riedl et al. 2006).

HERBICIDES/PLANT GROWTH REGULATORS/ADJUVANTS

Adjuvants: In general, most spray adjuvants are not believed to be toxic to bees. Three exceptions have been reported however, including: Pulse (organosilicone surfactant), Boost (organosilicone), and Ethokem (polyethanoxy alkylamine, ethoxylated tallow amine) (Mussen 2006).

Corn Gluten: When applied according to label directions, it is unlikely that corn gluten will have any adverse effects on bees (EPA 2002).

Gibberellic Acid: This plant growth regulator has been reported as relatively non-toxic to bees (EPA 1995).

Horticultural Vinegar: No information is available on the effects of horticultural vinegar on pollinators. It may be harmful if it is directly applied to foraging bees, so reasonable caution should be exercised.

FUNGICIDES

Copper: Copper fungicides have been reported to negatively effect some bee survival and reproduction (Applied Bio-nomics, Ltd 2006). Its use should be minimized where bees are present.

Copper Sulfate: Bordeaux mixture of copper sulfate, lime, and water, as well as other water-based copper fungicides have been reported to be harmful to bees (Pesticide Information Project 1994b). Avoid where pollinators are present.

Lime Sulfur: Based upon limited documentation, lime sulfur can be applied with reasonable safety to bees (Riedl et al. 2006).

Sulfur: Some impact on bee survival and reproduction has been reported from sulfur use, and where managed pollinators are present, hives should be removed or covered. Toxic residuals may persist for one-and-a-half days (Applied Bio-nomics, Ltd 2006, Koppert Biological Systems 2007).

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Dozens of species of native bee pollinate flowers on the low-bush blueberry barrens in the Northeast United States and southeast Canada. Protecting these insects from pesticides is important to maintain large harvests. Photograph by Eric Mader.

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INVERTEBRATE CONSERVATION FACT SHEET

Tunnel Nests for Native Bees

Nest Construction and Management

There are many simple and successful ways to make artificial nests for native bees.

However, keeping the nests clean is important to limit disease build-up and maintain healthy bee populations.

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Artificial nest sites like bamboo tubes in a plastic bucket are effective, but need maintenance. *Photograph by Eric Mader*

About 30 percent of the four thousand species of bees native to North America nest in small tunnels such as hollow plant stems, abandoned borer-beetle holes in snags, and similar locations. This includes some of our best known native bees, the blue orchard bees and leafcutters. The absence of these features in intensively farmed landscapes can limit nesting opportunities for these important crop pollinators.

Artificial nests consisting of wood blocks drilled with a large number of dead-end tunnels have been promoted as a way to attract bees and boost their local populations. This can be an effective way to enhance bee populations but these nests do need some tending to maintain the benefits. This fact sheet provides an overview of tunnel-nesting bee biology, and guidance on how to make and manage nests.

TUNNEL-NESTING BEE BIOLOGY

The vast majority of native bee species, including tunnel-nesting bees, lead solitary lives. While they may have gregarious tendencies, preferring to nest near other members of their species, each female individually constructs her own nest and provisions it with food for her offspring.

To make a nest, a female bee builds partitions to divide the tunnel into a linear row of brood cells. Depending on the species, the partitioning walls may be constructed of mud, plant resins, leaf pieces, flower petals, and even cellophane-like glandular secretions.

The female provisions each brood cell with a mixture of pollen and nectar, onto which she lays a single egg before sealing the cell and moving on to supply the next cell. Her offspring pass through the egg, larval, and pupal stages in the cell before emerging as adults to renew the cycle, usually the following year. After several weeks of nesting, the mother bee generally dies.

Nesting bees may not fill the entire length of a tunnel with cells, or they may die before an entire length of a tunnel is filled. For these reasons it can be difficult to tell if a nest tunnel is occupied from outside observation. A bee that is able to fill an entire tunnel with eggs before dying will plug the tunnel entrance with mud, leaf pieces, or other nesting substrates to prevent predators from attacking her brood.

Bees have the unique ability to determine the sex of the egg they lay; most male eggs are laid closest to the tunnel entrance. Because each female may mate with several males, males are more expendable from an ecological standpoint. Thus, the advantage of laying male eggs closer to the nest entrance is that they are the first to fall victim to predators such as nest-invading insects, or woodpeckers, while the developing females remain safe deeper within the nest. Being closer to the entrance, male bees emerge prior to the females, and will often wait outside, ready to mate with the females who will appear several days later.

Depending on the species and climate, there may only be a single generation of bees per year (univoltinism), or multiple generations per year (multivoltinism). Some species may also have parsivoltine lifecycles, laying dormant for over a year, waiting for the appropriate weather conditions to spur their emergence. The latter lifecycle is most commonly observed at high elevations, in deserts, areas prone to forest fires, and other extreme environments.

About 30 percent of North America's bee species nest in tunnels, generally abandoned beetle borings in a snag or, as here, the center of a pithy twig. The female bee divides the tunnel into a series of brood cells, each one supplied with nectar and pollen. Small carpenter bee (genus *Ceratina*), photographed by Edward S. Ross.

Making Artificial Nests

Commercially produced bee blocks, consisting of a wood block drilled with a series of dead-end tunnels are now widely available. These types of bee nests were initially developed in the 1960s by alfalfa seed producers in the western U.S. to attract and manage large numbers of the non-native alfalfa leafcutter bee (*Megachile rotundata*). More recently artificial nests have been modified to manage the blue orchard bee (*Osmia lignaria*) for orchard fruit and almond pollination. These artificial nests contain tunnels that are a uniform size and depth. However, because they are designed to suit specific species, they may be either too large or too small for many other species. Also, the blue orchard bee is active only in the spring and will not pollinate later-flowering fruits and vegetables. Nest blocks with a greater diversity of hole sizes and depths are necessary to attract a variety of bees that are active throughout the year.

Under the best circumstances artificial nests can attract large numbers of tunnel-nesting bees and boost their local populations. However because these nests concentrate bee populations in unnaturally large numbers in a small space, they can become infested with parasites and disease spores after several seasons.

Without regular sanitation or the phasing out of nest materials, these parasites and diseases threaten long-term pollinator health wherever they are used. Because contaminated nest blocks left unattended in the landscape continue to attract wild bees from the surrounding area, they have the potential to do harm. With proper management, however, these nests can maintain healthy bee populations indefinitely.

Wooden Blocks

To construct wooden nest blocks use preservative-free dimensional lumber: 4 by 4 for blocks with smaller diameter tunnels (¼" or less), or 4 by 6 for blocks with larger diameter tunnels (greater than ¼").

In one side, drill a series of nest tunnels between 3⁄32" and 3⁄8" in diameter. We recommend that you have only one diameter of tunnel in each block. Tunnels of ¼" or less in diameter should be 3" to 5" deep. Tunnels larger than ¼" should be 5" to 6" deep. Because the female bee controls the gender of her offspring and usually finishes the nest with a few male brood cells, a deeper tunnel ensures space for more female brood.

The tunnels should be about ¾" from center to center, and no closer than that to the edges. Attach a backing board if you drill all the way through your block, because bees will not use a tunnel that is open at both ends. With smaller diameter drill bits, you may not be able to

Two styles of tunnel nest: a wooden block (left) and a stem bundle (right, being sealed by a mason bee). The wooden block can be redrilled and washed to maintain nest hygiene. The stem bundle must be disposed of after a couple of years and replaced. Photographs by Matthew Shepherd (L) and Mace Vaughan (R).

achieve the 3-inch minimum recommended depth. If that is the case, simply drill as deeply as you can; bees that use tunnels of smaller diameters will often nest successfully in ones that aren't as deep.

Bees may avoid a rough interior, so tunnels should be perpendicular to the wood's grain, and drilled with a sharp bit. You can buy paper straws to line the holes, although it may be hard to find straws that fit all diameters. One solution is to wrap your own paper straws out of parchment or newspaper using dowels of various diameters that match the inside diameters of your drilled tunnels. Paint the outer tips of the straws black to help attract bees.

The exterior of the block can be any color, although there is some anecdotal evidence that bees are most attracted to dark blocks, which can be achieved by lightly charring the front surface with a propane torch. Whatever the color, bees are likely to use it as long as the tunnels are of appropriate diameters and depths, and hung in an appropriate location. As a final step, attach an overhanging roof to provide additional shelter from the rain.

Colonization by wild bees is often more successful when blocks are attached to a large visible landmark (such as a building), rather than hanging from fence posts or trees. Another drawback of hanging nest blocks from trees or fence posts is that they are likely to move or shake in the wind, which is disruptive to nesting and larval development. Nest blocks should be at least a few feet off the ground to avoid getting splashed by rain or covered by vegetation. They should be hung in a bright but protected location. Direct sunshine in the morning will help bees warm themselves up to flight temperature, so if possible place nests facing east, allowing the morning sun to fall on the entrance holes. However, direct sunlight later in the day can be detrimental, causing brood to die.

To protect against woodpecker damage, store nests in an unheated building at the end of the season. Alternatively, they can be protected over the winter by surrounding them with hardware cloth. Be sure to remove it before nesting resumes as hardware cloth can disorient nesting bees and damage their wings.

Stem Bundles

In addition to wooden blocks, artificial nests can be constructed with bundles of reed, teasel, cup plant, or bamboo, cut so that a natural node forms the inner wall of the tunnel.

Cut each stem below the nodes (usually indicated

Three styles of tunnel nest suitable for crop pollination.
Top: Bamboo stems in plastic tubs. The lidded tub on the top left is an emergence box, allowing replacement of the stems, and the chicken wire protects the bees' nests from woodpeckers.
Middle: Commercially made grooved wooden boards, occupied by leafcutter bees. The boards can be separated to expose the brood cells for cleaning.
Bottom: Styrofoam blocks molded with nest tunnels. This is designed for leafcutter bees and have raised designs to help bees locate their nest.
Photographs by Eric Mader.

by a ridge) to create a handful of tubes each with one open end. Strap the tubes together into a tight bundle with wire, string, or tape, making certain that the closed ends of the stems are all at the same end of the bundle. A variation on this is to tightly pack the stems—open ends out—into a tin can, paper milk carton, square plastic buckets,, short section of PVC pipe, or other container. The bundles should be placed in a sheltered location (such as the side of a barn or garden shed) with the stems horizontal to the ground.

Adobe Blocks

Some solitary bees nest in cracks, or cavities in soft sandstone and dry exposed soil embankments. Some of these species, such as *Anthophora abrupta*, and *Anthophora urbana*, two important visitors of some fruit and vegetable crops, will excavate tunnels in cliff sides by using water or nectar to soften the hard soil surface. These species are quite common in the southeastern and southwestern U.S. respectively.

To attract these species, adobe bricks can serve as the equivalent of a wooden nest block. Such bricks can sometimes be purchased, in which case you can increase their attractiveness to bees by drilling nesting holes following the size recommendations listed above for wood blocks.

Adobe blocks can also be easily made where clay soils are common. To create one, half-fill a large bucket with clay soil, then fill the bucket with water. Stir the mixture together, creating a slurry, and allow it to settle. Remove any sticks or debris floating on the surface, and slowly pour off most of the water. Finally, pour the remaining sediment into a mold (such as a wooden box or small Styrofoam cooler), and allow it to dry for several days or weeks. Before it completely dries, make several one-inch-deep indentations, using the diameter guidelines above, to make it more attractive to bees.

Mount the brick, either singularly, or in a stack. Adobe will not hold up well in wet climates, and many need sheltering from rain.

Maintenance of Tunnel Nests

Regardless of type, the tunnel-nest will need routine management and regular replacement to prevent the build-up of parasites and diseases that affect the developing brood.

The hardest of these to control is the fungal disease chalkbrood (*Ascosphaera* spp.). Several species of the fungi exist among cavity nesting bees, all of which are different from the chalkbrood disease that attacks honey bees. Bee larvae become infested with disease spores through contaminated pollen, either collected from a flower by the mother bee, or accidentally spread when the mother bee

Artificial nest sites lead to bees nesting in densities seldom reached in naturally, and pests and diseases can proliferate unless the nests are carefully maintained. This bamboo stem has been infested with chalkbrood; none of the bees survived. Photograph by Eric Mader.

emerges from a contaminated nest tunnel.

After they are ingested, the chalkbrood spores germinate inside the gut of the developing larva, producing long filaments (hyphae) that eventually penetrate the gut wall, killing the larva. These dead larvae pose a hazard to bees deeper within the nest block that, upon emergence, must climb over or chew through the spore-infested cell to escape the nest. Bees that emerge under these circumstances have a high likelihood of spreading the spores to their own offspring. Similarly, bees searching for unoccupied nest tunnels in which to lay their eggs frequently investigate, and often select, previously used tunnels. Over time, chalkbrood spores are spread throughout a nest block in this way.

Along with chalkbrood, pollen mites in the genus *Chaetodactylus* can be a persistent problem in nest blocks that are in continuous use for several seasons. Unlike the mites that attack honey bees, pollen mites do not feed on the hemolymph (blood) of the bee. Instead, pollen mites are “cleptoparasites,” feeding on the pollen provision and causing the developing bee larva to starve.

Adult pollen mites are white, tan, or orange in color and measure about 500 microns in width (about the size of the period at the end of this sentence). As with chalkbrood, adult bees may accidentally pick up mites at flowers while foraging, or when emerging from contaminated nest tunnels. Migratory mite nymphs cling to a bee’s hair and are transported to new brood cells where they feed on the pollen provision and reproduce rapidly. In a single provisioned cell, mite numbers can quickly climb into the thousands. While pollen mites usually cannot break through cell partitions, they can persist for many months without food, until a bee deeper within the nest emerges from the tunnel and breaks the partition walls, allowing them to escape. It is not uncommon to see bees emerging from infested nest blocks covered with so many migratory mite nymphs that they have difficulty flying.

Nest Block Sanitation

With appropriate management, the worst parasite and disease problems can be minimized or avoided. Specifically, one of three approaches should be taken:

Use Paper Straws

The holes of wood nest blocks can be lined with tight-fitting removable paper straws. To facilitate removal, and prevent excess drying of the pollen provision, some beekeepers use custom manufactured waxed paper straws. At the end of the nesting season (autumn), the straws are gently removed, and placed in a ventilated container and stored either in a refrigerator, or an unheated barn or garage. The nest block is then disinfected by submerging it in a weak bleach-water solution for a few minutes. In the spring, fill the block with clean, unused paper straws and return it to its location. The old straws (with bees in them) are placed alongside the nest block, and the bees allow to emerge naturally. When the old straws are empty, they are disposed of.

Replace Nest Blocks

Nest blocks, and stem bundles can be phased out every two years by placing them inside a dark container, such as a light-proof wooden box, a dark-colored plastic bucket with a tight-fitting lid, or even a sealed milk carton that has been spray-painted black to reduce light infiltration. A single ⅜" exit hole is drilled in the bottom of the light-proof container, and the entire contraption is hung adjacent to a new, previously unused nest block or stem bundle. To facilitate ease of exit, this escape hole should be located on the bottom of the dark container so that bees can crawl, rather than attempt to fly out.

As bees emerge from the old nest, they are attracted to the light of the exit hole, and emerge to find the new nest hanging near by.

Unless a single bee species with a known emergence time is being managed, leave the nest block inside the emergence box for a full year. Even under this timeline not all parsivoltine species may emerge. If this is a concern, leave nest blocks in the emergence box for two seasons.

After bees have been allowed to emerge from the nest block, clean it by re-drilling the tunnels to loosen any debris then submerge it in a solution of bleach and water (1:2 by volume) for five minutes. Even when cleaned in this way some viable chalkbrood spores may be present. The only guarantee against chalkbrood is the complete disposal of old nests.

Several Small Blocks

The last alternative is to create multiple small nest blocks or stem bundles with only a few nest tunnels (four to six), and hang them at widely distant intervals. This prevents the unnaturally high populations of bees found at nest blocks with many holes, and mimics natural conditions of limited, spatially separated nest sites. These smaller nests also decompose more rapidly, and can be allowed to simply deteriorate naturally, while new small nests are added to the landscape periodically.

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The Xerces Society for Invertebrate Conservation

Invertebrate Conservation Fact Sheet

Nests for Native Bees

Pollinators are a vital part of a healthy environment.

Native bees are North America's most important group of pollinators.

Nest sites are simple to make, and can be added to any area of greenspace, large or small.

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A selection of home-made bee nests: (clockwise from left) wooden block, bamboo bundle, and bumble bee box.

Pollinators are a diverse and fascinating group of animals. In addition to their beauty, pollinators provide an important link in our environment by moving pollen between flowers and ensuring the growth of seeds and fruits. The work of pollinators touches our lives every day through the food we eat. Even our seasons are marked by their work: the bloom of springtime meadows, summer berry picking, pumpkins in the fall.

There are 4,000 species of native bees in North America. Together they form the most important group of pollinators. Like all wildlife they are affected by changes in our landscapes, especially the loss of nesting sites. Bees make nests in which they create and provision brood cells for their offspring. In many modern landscapes, a desire for neatness has usually resulted in the removal of bare ground, dead trees, and untidy corners of rough grass—all important nesting sites for bees.

This fact sheet gives information on how to provide nest sites for native bees, including nest blocks and bare ground for solitary-nesting bees, and nesting boxes for bumble bees.

For more information, visit our web site, www.xerces.org, where you will find other fact sheets and more detailed guidelines on how to enhance habitat for pollinators. You'll also find information about the *Pollinator Conservation Handbook*.

Wood-Nesting and Cavity-Nesting Bees

About 30 percent of our native bee species make their nests in old beetle tunnels in snags or similar locations. The female bee builds dividing walls across the tunnel to make a line of brood cells. Where you can, retain snags. Where you can't, make some nesting blocks. (Alternatively, many garden centers and back yard bird shops sell them.)

- **Nesting blocks.** Bee blocks can be made by drilling nesting holes between 3/32" and 3/8" in diameter, at approximate 3/4" centers, into the side of a block of preservative-free lumber. The holes should be smooth inside, and closed at one end. The height of the nest is not critical—8" or more is good—but the depth of the holes is. Holes less than 1/4" diameter should be 3-4" deep. For holes 1/4" or larger, a 5-6" depth is best.
- **Adobe blocks.** In desert areas, adobe blocks can be made and drilled with holes as outlined above.
- **Logs and snags.** Get some logs or old stumps and place them in sunny areas. Those with beetle tunnels are ideal. Plant a few upright, like dead trees, to ensure some deadwood habitat stays dry. On the southeast side of each log, drill a range of holes, as outlined above.
- **Stem or tube bundles.** Some plants, like teasel, bamboo, and reeds, have naturally hollow stems. Cut the stems into 6" to 8" lengths. Be careful to cut the stems close to a stem node to create a tube with one end closed. Fifteen to twenty stem pieces tied into a bundle (with the closed ends of the stems together) makes a fine nest. Or, make a wooden frame to hold as many stems as you like. Paper tubes can be used as well. Just make sure they stay dry.

Location of the nesting sites is important. These nests should be placed where they are sheltered from the worst of the weather, with entrance holes facing towards east or southeast, so they get the morning sun. With stem bundles, be sure that the stems are horizontal. The nests can be any height from the ground, but between three and six feet is convenient. Put them on a building , fence, or stake, or place them in a tree. Fix them firmly so they don't shake in the wind.

Ground-Nesting Bees

Most native bees—about 70 percent of species—nest in the ground, and need access to the soil surface to dig their nest. Each female excavates her own nest tunnel and brood cells, and stocks the cells with nectar and pollen. Where possible, keep bare or partially vegetated ground. Where you can, create more.

- **Bare ground.** Simply clear the vegetation from small patches of level or sloping ground and gently compact the soil surface. These patches can be from a few inches to a few feet across, but should be well drained, and in an open, sunny place. A south-facing slope can be a good location. Different ground conditions—from vertical banks to flat ground—will draw different bee species, so create nesting patches in different areas if you can to maximize the nesting opportunities.
- **Sand pits and piles.** In a sunny, well-drained spot, dig a pit about 2' deep, and fill it with a mixture of pale-colored, fine-grained sand and loam. Where soils do not drain well, a pile of the sand/loam mixture can help, or make a raised bed. If space is limited, you can fill planter boxes with the sand/loam mixture.

Bumble Bees

Unlike the nests built for solitary bees there are no strict size requirements for bumble bee nests—any hole large enough for a small colony will be OK. After emerging from hibernation, a bumble bee queen will hunt for a dry, warm cavity in which to start her colony. In natural conditions, most bumble bees nest in abandoned mouse holes in the ground or under grass tussocks. Where you can, keep patches of rough grass. Where you can't, consider building a nest box or two.

- **Nest box.** A simple wooden box, with internal dimensions of about 7" by 7" by 7", made from preservative-free lumber will work. Drill a few ventilation holes near the top (covered with door screen to deter ants) and some drainage holes in the bottom. Make an entrance tunnel from 3/4" plastic pipe, marked on the outside with a contrasting color, and fill the box with soft bedding material, such as upholsterer's cotton or short lengths of unraveled, soft string. The box must be weather tight; the larvae may become cold in a damp nest, and mold and fungus will grow.

Place the box in an undisturbed site, in partial or full shade, where there is no risk of flooding. The box should be on or just under the ground. If you bury it, extend the entrance tube so it gently slopes up to the surface. Put your nesting box out when you first notice bumble bees in the spring, or when the first willows and other flowers are blooming, and be patient. There is no guarantee that bees will use your box. Only about one in four boxes get occupied. If it has no inhabitants by late July, put the nesting box into storage until next spring.

For more pollinator conservation information, go to www.xerces.org

INVERTEBRATE CONSERVATION FACT SHEET

Plants for Native Bees

in North America

Pollinators are a vital part of a healthy environment.

Native bees are North America's most important group of pollinators.

Patches of flowers can be grown almost anywhere and will form an important food resource for bees.

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Melissodes bee foraging on sunflower. *Photograph © Edward S. Ross*

Pollinators are a diverse and fascinating group of animals. In addition to their beauty, pollinators provide an important service in our environment by moving pollen between flowers and ensuring the growth of seeds and fruits. Pollinators touch our lives every day through the food we eat. Even our seasons are marked by their work: the bloom of springtime meadows, summer berry picking, pumpkins in the fall.

Native bees are the most important group of pollinators. Like all wildlife they are affected by changes in our landscapes. The good news is that there are straightforward things that you can do to help: providing patches of flowers is something that we all can do to improve our environment for these important insects. Native plants are undoubtedly the best source of food for bees, but there are also some garden plants that are great for pollinators.

This fact sheet will help you provide the flowers that these vital animals need and make the landscape around us—from small urban backyards to large natural areas—better for bees. On the back you'll find a simple guide to selecting plants for bees.

For more information, visit our web site, www.xerces.org, where you will find other fact sheets and more detailed guidelines on how to enhance habitat for pollinators. You'll also find information about the *Pollinator Conservation Handbook*.

Choosing the Right Flowers

To help bees and other pollinator insects—like butterflies—you should provide a range of plants that will offer a succession of flowers, and thus pollen and nectar, through the whole growing season. Patches of foraging habitat can be created in many different locations, from backyards and school grounds to golf courses and city parks. Even a small area planted with the right flowers will be beneficial, because each patch will add to the mosaic of habitat available to bees and other pollinators.

In such a short fact sheet it is not possible to give detailed lists of suitable plants for all regions. Below are two lists of good bee plants, the first of native plants and the second of garden plants. Both are short lists; there are many more bee-friendly plants. However, these lists, combined with the following notes, will get you started on selecting good bee plants. Your local chapter of the Native Plant Society and native plant nurseries are worthwhile contacts for advice on choosing, obtaining, and caring for local plant species.

- **Use local native plants.** Research suggests native plants are four times more attractive to native bees than exotic flowers. In gardens, heirloom varieties of herbs and perennials can also provide good foraging.
- **Choose several colors of flowers.** Flower colors that particularly attract bees are blue, purple, violet, white, and yellow.
- **Plant flowers in clumps.** Flowers clustered into clumps of one species will attract more pollinators than individual plants scattered through the habitat patch. Where space allows, make the clumps four feet or more in diameter.
- **Include flowers of different shapes.** Bees are all different sizes, have different tongue lengths, and will feed on different shaped flowers. Consequently, providing a range of flower shapes means more bees can benefit.
- **Have a diversity of plants flowering all season**. By having several plant species flowering at once, and a sequence of plants flowering through spring, summer, and fall, you can support a range of bee species that fly at different times of the year.

Native Plants

Native plants should be your first choice to help our native bees. Listed below are some plants that are good sources of nectar or pollen for bees. This list is not exhaustive; there are many other plants good for bees. Individual species have not been included. Not all of these genera will have species in your local area, but they do represent plants that will grow in a variety of environments. Use a wildflower guide or contact local nurseries to find your local species.

Aster	*Symphyotrichum*	Oregon grape	*Mahonia*
Buckwheat	*Eriogonum*	Penstemon	*Penstemon*
Bee balm	*Monarda*	Prairie clover	*Dalea*
Blazing star	*Liatris*	Purple coneflower	*Echinacea*
Ceanothus, buckbrush	*Ceanothus*	Rabbitbrush	*Chrysothamnus*
Creosote bush	*Larrea*	Rhododendron	*Rhododendron*
Currant	*Ribes*	Sage	*Salvia*
Giant hyssop	*Agastache*	Scorpion-weed	*Phacelia*
Goldenrod	*Solidago*	Snowberry	*Symphoricarpos*
Joe-pye weed	*Eupatorium*	Spiderwort	*Tradescantia*
Lupine	*Lupinus*	Sunflower	*Helianthus*
Milkweed	*Asclepias*	Willow	*Salix*

Garden Plants

Flower beds in gardens, business campuses, and parks are great places to have bee-friendly plants. Native plants will create a beautiful garden but some people prefer "garden" plants. Many garden plants are varieties of native plants. This list includes plants from other countries—"exotic" plants—and should be used as a supplement to the native plant list. As with the native plants, this list is far from exhaustive.

Basil	*Ocimum*	English lavender	*Lavandula*
Borage	*Borago*	Marjoram	*Origanum*
Blanketflower	*Gaillardia*	Mexican sunflower	*Tithonia*
Catnip	*Nepeta*	Rosemary	*Rosmarinus*
Cotoneaster	*Cotoneaster*	Russian sage	*Perovskia*

For more pollinator conservation information, go to www.xerces.org

INVERTEBRATE CONSERVATION FACT SHEET

Pacific Northwest Plants

for Native Bees

Pollinators are a vital part of a healthy environment.

Native bees are North America's most important group of pollinators.

Patches of flowers can be grown almost anywhere and will form an important food resource for bees.

Leafcutter bee foraging on gumweed. *Photograph © Edward S. Ross*

Pollinators are a diverse and fascinating group of animals. In addition to their beauty, pollinators provide an important service in our environment by moving pollen between flowers and ensuring the growth of seeds and fruits. Pollinators touch our lives every day through the food we eat. Even our seasons are marked by their work: the bloom of springtime meadows, summer berry picking, pumpkins in the fall.

Native bees are the most important group of pollinators. Like all wildlife they are affected by changes in our landscapes. The good news is that there are straightforward things that you can do to help: providing patches of flowers is something that we all can do to improve our environment for these important insects. Native plants are undoubtedly the best source of food for bees, but there are also some garden plants that are great for pollinators.

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Matthew Shepherd

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Choosing the Right Flowers

To help bees and other pollinator insects—like butterflies—you should provide a range of plants that will offer a succession of flowers, and thus pollen and nectar, through the whole growing season. Patches of foraging habitat can be created in many different locations, from backyards and school grounds to golf courses and city parks. Even a small area planted with the right flowers will be beneficial, because each patch will add to the mosaic of habitat available to bees and other pollinators.

In such a short fact sheet it is not possible to give detailed lists of suitable plants for all areas of the Pacific Northwest. Below are two lists of good bee plants, the first of native plants and the second of garden plants. Both are short lists; there are many more bee-friendly plants. However, these lists, combined with the following notes, will get you started on selecting good bee plants. Your local chapter of the Native Plant Society and native plant nurseries are worthwhile contacts for advice on choosing, obtaining, and caring for local plant species.

- **Use local native plants.** Research suggests native plants are four times more attractive to native bees than exotic flowers. In gardens, heirloom varieties of herbs and perennials can also provide good foraging.
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- **Include flowers of different shapes.** Bees are all different sizes, have different tongue lengths, and will feed on different shaped flowers. Consequently, providing a range of flower shapes means more bees can benefit.
- **Have a diversity of plants flowering all season**. By having several plant species flowering at once, and a sequence of plants flowering through spring, summer, and fall, you can support a range of bee species that fly at different times of the season.

Native Plants

Native plants should be your first choice to help our native bees. Listed below are some plants that are good sources of nectar or pollen for bees. This list is not exhaustive; there are many other plants good for bees. Individual species have not been included. Not all of these genera will have species in your local area, but they do represent plants that will grow in a variety of environments. Use a wildflower guide or contact local nurseries to find your local species.

Aster	*Symphyotrichum*	Lupine	*Lupinus*
Balsamroot	*Balsamorhiza*	Ninebark	*Physocarpus*
Blanketflower	*Gaillardia*	Oceanspray	*Holodiscus*
Buckwheat	*Eriogonum*	Oregon grape	*Mahonia*
California poppy	*Eschscholzia*	Penstemon	*Penstemon*
Ceanothus, buckbrush	*Ceanothus*	Phacelia	*Phacelia*
Clarkia	*Clarkia*	Rabbitbrush	*Chrysothamnus*
Currant	*Ribes*	Rose	*Rosa*
Fireweed	*Chamerion*	Serviceberry	*Amalanchier*
Goldenrod	*Solidago*	Snowberry	*Symphoricarpos*
Gumplant	*Grindelia*	Sunflower	*Helianthus*
Huckleberry	*Vaccinium*	Willow	*Salix*

Garden Plants

Flower beds in gardens, business campuses, and parks are great places to have bee-friendly plants. Native plants will create a beautiful garden but some people prefer "garden" plants. Many garden plants are varieties of native plants. This list includes plants from other countries—"exotic" plants—and should be used as a supplement to the native plant list. As with the native plants, this list is far from exhaustive.

Basil	*Ocimum*	Marjoram	*Origanum*
Borage	*Borago*	Mexican sunflower	*Tithonia*
Catnip	*Nepeta*	Mint	*Mentha*
English lavender	*Lavandula*	Purple coneflower	*Rudbeckia*
Giant hyssop	*Agastache*	Rosemary	*Rosmarinus*

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INVERTEBRATE CONSERVATION FACT SHEET

California Plants

for Native Bees

Pollinators are a vital part of a healthy environment.

Native bees are North America's most important group of pollinators.

Patches of flowers can be grown almost anywhere and will form an important food resource for bees.

Mining bee foraging on sunflower. *Photograph © Edward S. Ross*

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Choosing the Right Flowers

To help bees and other pollinator insects—like butterflies—you should provide a range of plants that will offer a succession of flowers, and thus pollen and nectar, through the whole growing season. Patches of foraging habitat can be created in many different locations, from backyards and school grounds to golf courses and city parks. Even a small area planted with the right flowers will be beneficial, because each patch will add to the mosaic of habitat available to bees and other pollinators.

In such a short fact sheet it is not possible to give detailed lists of suitable plants for all areas of California. Below are two lists of good bee plants, the first of native plants and the second of garden plants. Both are short lists; there are many more bee-friendly plants. However, these lists, combined with the following notes, will get you started on selecting good bee plants. Your local chapter of the Native Plant Society and native plant nurseries are worthwhile contacts for advice on choosing, obtaining, and caring for local plant species.

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Native Plants

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Aster	*Symphyotrichum*	Hollyleaf cherry	*Prunus*
Baby blue eyes	*Nemophila*	Horkelia	*Horkelia*
Bluecurls	*Trichostema*	Lupine	*Lupinus*
Buckwheat	*Eriogonum*	Manzanita	*Arctostaphylos*
California lilac	*Ceanothus*	Oceanspray	*Holodiscus*
California poppy	*Eschscholzia*	Oregon grape	*Mahonia*
Clarkia	*Clarkia*	Phacelia	*Phacelia*
Coffeeberry	*Rhamnus*	Redbud	*Cercis*
Coyotebrush	*Baccharis*	Rose	*Rosa*
Fremontia	*Fremontodendron*	Sage	*Salvia*
Goldenrod	*Solidago*	Sunflower	*Helianthus*
Gumweed	*Grindelia*	Toyon	*Heteromeles*

Garden Plants

Flower beds in gardens, business campuses, and parks are great places to have bee-friendly plants. Native plants will create a beautiful garden but some people prefer "garden" plants. Many garden plants are varieties of native plants. This list includes plants from other countries—"exotic" plants—and should be used as a supplement to the native plant list. As with the native plants, this list is far from exhaustive.

Catnip	*Nepeta*	Oregano	*Origanum*
Cosmos	*Cosmos*	Russian sage	*Perovskia*
Giant hyssop	*Agastache*	Rosemary	*Rosemarinus*
Lavender	*Lavandula*	Sea holly	*Eryngium*
Mexican sunflower	*Tithonia*	Thyme	*Thymus*

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INVERTEBRATE CONSERVATION FACT SHEET

Upper Midwest Plants
for Native Bees

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Native bees are North America's most important group of pollinators.

Patches of flowers can be grown almost anywhere and will form an important food resource for bees.

Bumble bee foraging on beebalm. *Photo by Eric Mader*

Pollinators are a diverse and fascinating group of animals. In addition to their beauty, pollinators provide an important link in our environment by moving pollen between flowers and ensuring the growth of seeds and fruits. The work of pollinators touches our lives every day through the food we eat. Even our seasons are marked by their work: the bloom of springtime meadows, summer berry picking, pumpkins in the fall.

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Choosing the Right Flowers

To help bees and other pollinator insects—like butterflies—you should provide a range of plants that will offer a succession of flowers, and thus pollen and nectar, through the whole growing season. Patches of foraging habitat can be created in many different locations, from backyards and school grounds to golf courses and city parks. Even a small area planted with the right flowers will be beneficial, because each patch will add to the mosaic of habitat available to bees and other pollinators.

In such a short fact sheet it is not possible to give detailed lists of suitable plants for all areas of the Upper Midwest. Below are two lists of good bee plants, the first of native plants and the second of garden plants. Both are short lists; there are many more bee-friendly plants. However, these lists, combined with the following notes, will get you started on selecting good bee plants. Your local chapters of the Wild Ones, the Native Plant Society and native plant nurseries are worthwhile contacts for advice on choosing, obtaining, and caring for local plant species.

- **Use local native plants.** Research suggests native plants are four times more attractive to native bees than exotic flowers. In gardens, heirloom varieties of herbs and perennials can also provide good foraging.
- **Choose several colors of flowers.** Flower colors that particularly attract native bees are blue, purple, violet, white, and yellow.
- **Plant flowers in clumps.** Flowers clustered into clumps of one species will attract more pollinators than individual plants scattered through the habitat patch. Where space allows, make the clumps four feet or more in diameter.
- **Include flowers of different shapes.** Bees are all different sizes, have different tongue lengths, and will feed on different shaped flowers. Consequently, providing a range of flower shapes means more bees can benefit.
- **Have a diversity of plants flowering all season.** By having several plant species flowering at once, and a sequence of plants flowering through spring, summer, and fall, you can support a range of bee species that fly at different times of the season.

Native Plants

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Aster	*Aster*	Lupine	*Lupinus*
Beebalm	*Monarda*	Milkweed	*Asclepias*
Blazing star	*Liatris*	New Jersey tea	*Ceanothus*
Cup plant	*Silphium*	Obedient plant	*Physostegia*
Wild indigo	*Baptisia*	Penstemon	*Penstemon*
Fireweed	*Chamerion*	Prairie clover	*Dalea*
Goldenrod	*Solidago*	Purple coneflower	*Echinacea*
Giant hyssop	*Agastache*	Rattlesnake master	*Eryngium*
Ironweed	*Vernonia*	Spiderwort	*Tradescantia*
Joe Pye weed	*Eupatorium*	Steeplebush	*Spiraea*
Leadplant	*Amorpha*	Sunflower	*Helianthus*
Lobelia	*Lobelia*	Willow	*Salix*

Garden Plants

Flower beds in gardens, business campuses, and parks are great places to have bee-friendly plants. Native plants will create a beautiful garden but some people prefer “garden” plants. Many garden plants are varieties of native plants. This list includes plants from other countries—”exotic” plants—and should be used as a supplement to the native plant list. As with the native plants, this list is far from exhaustive.

Basil	*Ocimum*	Oregano/marjoram	*Origanum*
Borage	*Borago*	Rosemary	*Rosmarinus*
Catmint	*Nepeta*	Russian sage	*Perovskia*
Cosmos	*Cosmos*	Spearmint	*Mentha*
Lavender	*Lavandula*	Squill	*Scilla*

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South Central Plants
for Native Bees

Pollinators are a vital part of a healthy environment.

Native bees are North America's most important group of pollinators.

Patches of flowers can be grown almost anywhere and will form an important food resource for bees.

Longhorn bee foraging on sunflower. *Photo by Mace Vaughan*

Pollinators are a diverse and fascinating group of animals. In addition to their beauty, pollinators provide an important link in our environment by moving pollen between flowers and ensuring the growth of seeds and fruits. The work of pollinators touches our lives every day through the food we eat. Even our seasons are marked by their work: the bloom of springtime meadows, summer berry picking, pumpkins in the fall.

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In such a short fact sheet it is not possible to give detailed lists of suitable plants for all areas of the South Central region. Below are two lists of good bee plants, the first of native plants and the second of garden plants. Both are short lists; there are many more bee-friendly plants. However, these lists, combined with the following notes, will get you started on selecting good bee plants. Your local chapters of the Wild Ones, the Native Plant Society and native plant nurseries are worthwhile contacts for advice on choosing, obtaining, and caring for local plant species.

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Native Plants

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Aster	*Symphyotrichum*	Milkweed	*Asclepias*
Beardtongue	*Penstemon*	Mountain mint	*Pycnanthemum*
Beebalm	*Monarda*	Partridge pea	*Chamaecrista*
Blanketflower	*Gaillardia*	Prairie clover	*Dalea*
Blazing star	*Liatris*	Prairie coneflower	*Ratibida*
Crownbeard	*Verbesina*	Redbud	*Cercis*
Culver's root	*Veronicastrum*	Rosinweed	*Silphium*
Englemann's daisy	*Englemannia*	Sneezeweed	*Helenium*
False indigo	*Amorpha*	Spiderwort	*Tradescantia*
Goldenrod	*Solidago*	Sunflower	*Helianthus*
Hawthorn	*Crataegus*	Wild plum	*Prunus*
Ironweed	*Vernonia*	Wild rose	*Rosa*

Garden Plants

Flower beds in gardens, business campuses, and parks are great places to have bee-friendly plants. Native plants will create a beautiful garden but some people prefer "garden" plants. Many garden plants are varieties of native plants. This list includes plants from other countries—"exotic" plants—and should be used as a supplement to the native plant list. As with the native plants, this list is far from exhaustive.

Anise hyssop	*Agastache*	Mexican sunflower	*Tithonia*
Basil	*Ocimum*	Purple coneflower	*Echinacea*
Catmint	*Nepeta*	Pincushion flower	*Scabiosa*
Cosmos	*Cosmos*	Rosemary	*Rosmarinus*
Marjoram	*Origanum*	Russian sage	*Perovskia*

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Northeast Plants

for Native Bees

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Sweat bee. *Photo by Joseph Berger, bogwood.org*

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Choosing the Right Flowers

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In such a short fact sheet it is not possible to give detailed lists of suitable plants for all areas of the Northeast. Below are two lists of good bee plants, the first of native plants and the second of garden plants. Both are short lists; there are many more bee-friendly plants. However, these lists, combined with the following notes, will get you started on selecting good bee plants. Your local chapters of the Wild Ones, the Native Plant Society and native plant nurseries are worthwhile contacts for advice on choosing, obtaining, and caring for local plant species.

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Native Plants

Native plants should be your first choice to help our native bees. Listed below are some plants that are good sources of nectar and pollen for bees. This list is not exhaustive; there are many other plants good for bees. Individual species have not been included. Not all of these genera will have species in your local area, but they do represent plants that will grow in a variety of environments. Use a wildflower guide or contact local nurseries to find your local species.

Aster	*Symphyotrichum*	Mountain mint	*Pycnanthemum*
Azalea	*Rhododendron*	New Jersey tea	*Ceanothus*
Basswood	*Tilia*	Serviceberry	*Amelanchier*
Beebalm	*Monarda*	Sneezeweed	*Helenium*
Blueberry	*Vaccinium*	Spiderwort	*Tradescantia*
Boneset	*Eupatorium*	Sunflower	*Helianthus*
Goldenrod	*Solidago*	Turtlehead	*Chelone*
Hawthorn	*Crataegus*	Wild geranium	*Geranium*
Lobelia	*Lobelia*	Wild indigo	*Baptisia*
Lupine	*Lupinus*	Wild mint	*Mentha*
Meadowsweet	*Spiraea*	Wild rose	*Rosa*
Milkweed	*Asclepias*	Willow	*Salix*

Garden Plants

Flower beds in gardens, business campuses, and parks are great places to have bee-friendly plants. Native plants will create a beautiful garden but some people prefer “garden” plants. Many garden plants are varieties of native plants. This list includes plants from other countries—”exotic” plants—and should be used as a supplement to the native plant list. As with the native plants, this list is far from exhaustive.

Basil	*Ocimum*	Hyssop	*Agastache*
Blazing star	*Liatris*	Lavender	*Lavandula*
Borage	*Borago*	Purple coneflower	*Echinacea*
Catmint	*Nepeta*	Russian sage	*Perovskia*
Cosmos	*Cosmos*	Squill	*Scilla*

For more pollinator conservation information, go to www.xerces.org

INVERTEBRATE CONSERVATION FACT SHEET

Mid-Atlantic Plants
for Native Bees

Pollinators are a vital part of a healthy environment.

Native bees are North America's most important group of pollinators.

Patches of flowers can be grown almost anywhere and will form an important food resource for bees.

Written by
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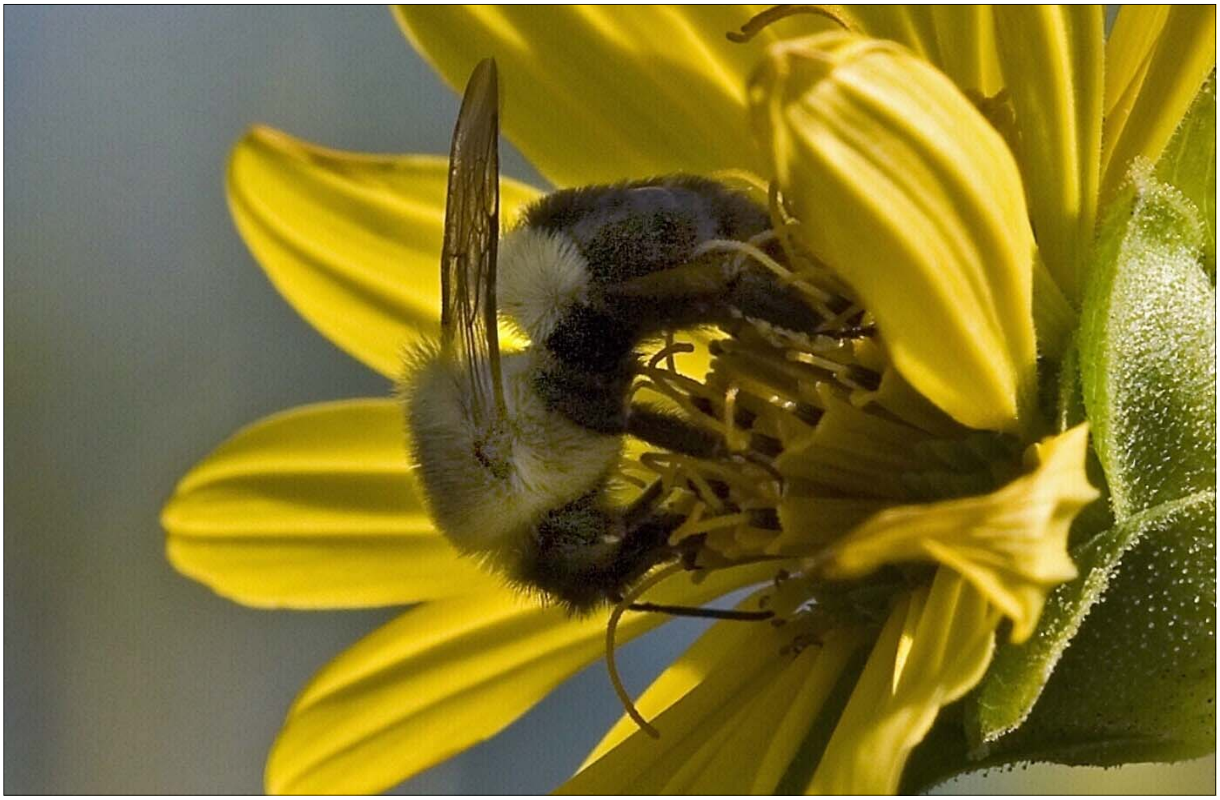

Common eastern bumble bee foraging on sunflower. *Photo by David Cappaert, bugwood.org*

Pollinators are a diverse and fascinating group of animals. In addition to their beauty, pollinators provide an important link in our environment by moving pollen between flowers and ensuring the growth of seeds and fruits. The work of pollinators touches our lives every day through the food we eat. Even our seasons are marked by their work: the bloom of springtime meadows, summer berry picking, pumpkins in the fall.

Native bees are the most important group of pollinators. Like all wildlife they are affected by changes in our landscapes. The good news is that there are straightforward things that you can do to help: providing patches of flowers is something that we all can do to improve our environment for these important insects. Native plants are undoubtedly the best source of food for bees, but there are also some garden plants that are great for pollinators.

This fact sheet will help you provide flowers that these vital creatures need and make the landscape around us—from small urban backyards to large natural areas—better for bees. On the back you'll find a simple guide to selecting plants for bees.

For more information, visit our web site, www.xerces.org, where you will find other fact sheets and more detailed guidelines on how to enhance habitat for pollinators. You'll also find information about the *Pollinator Conservation Handbook*.

Choosing the Right Flowers

To help bees and other pollinator insects—like butterflies—you should provide a range of plants that will offer a succession of flowers, and thus pollen and nectar, through the whole growing season. Patches of foraging habitat can be created in many different locations, from backyards and school grounds to golf courses and city parks. Even a small area planted with the right flowers will be beneficial, because each patch will add to the mosaic of habitat available to bees and other pollinators.

In such a short fact sheet it is not possible to give detailed lists of suitable plants for all areas of the Mid-Atlantic region. Below are two lists of good bee plants, the first of native plants and the second of garden plants. Both are short lists; there are many more bee-friendly plants. However, these lists, combined with the following notes, will get you started on selecting good bee plants. Your local chapters of the Wild Ones, the Native Plant Society and native plant nurseries are worthwhile contacts for advice on choosing, obtaining, and caring for local plant species.

- **Use local native plants.** Research suggests native plants are four times more attractive to native bees than exotic flowers. In gardens, heirloom varieties of herbs and perennials can also provide good foraging.
- **Choose several colors of flowers.** Flower colors that particularly attract native bees are blue, purple, violet, white, and yellow.
- **Plant flowers in clumps.** Flowers clustered into clumps of one species will attract more pollinators than individual plants scattered through the habitat patch. Where space allows, make the clumps four feet or more in diameter.
- **Include flowers of different shapes.** Bees are all different sizes, have different tongue lengths, and will feed on different shaped flowers. Consequently, providing a range of flower shapes means more bees can benefit.
- **Have a diversity of plants flowering all season.** By having several plant species flowering at once, and a sequence of plants flowering through spring, summer, and fall, you can support a range of bee species that fly at different times of the season.

Native Plants

Native plants should be your first choice to help our native bees. Listed below are some plants that are good sources of nectar and pollen for bees. This list is not exhaustive; there are many other plants good for bees. Individual species have not been included. Not all of these genera will have species in your local area, but they do represent plants that will grow in a variety of environments. Use a wildflower guide or contact local nurseries to find your local species.

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Azalea	*Rhododendron*	New Jersey tea	*Ceanothus*
Basswood	*Tilia*	Partridge pea	*Chamaecrista*
Beardtongue	*Penstemon*	Redbud	*Cercis*
Beebalm	*Monarda*	Serviceberry	*Amelanchier*
Culver's root	*Veronicastrum*	Sneezeweed	*Helenium*
Goldenrod	*Solidago*	Spiderwort	*Tradescantia*
Hawthorn	*Crataegus*	Sunflower	*Helianthus*
Hyssop	*Agastache*	Tuliptree	*Liriodendron*
Ironweed	*Vernonia*	Wild plum	*Prunus*
Joe-pye weed	*Eupatorium*	Wild rose	*Rosa*
Milkweed	*Asclepias*	Willow	*Salix*

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Catmint	*Nepeta*	Rosemary	*Rosmarinus*
Cosmos	*Cosmos*	Russian sage	*Perovskia*

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INVERTEBRATE CONSERVATION FACT SHEET

Pollinators in Natural Areas

A Primer on Habitat Management

Pollinators in natural areas support diverse plant communities, wildlife food webs, and adjacent farms.

Incorporating pollinator needs into a site management plan will result in excellent habitat for wildlife of all types.

Written by
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Anna's northern blue. *Photograph © Kim Davis and Mike Stangeland (www.kimandmikeontheroad.com)*

Plant pollination by animals is an essential ecosystem service. It is estimated that 60 to 80 percent of the world's 250,000 flowering plants depend on animals—mostly insects—for pollination (Kremen et al. 2007). Eighty-seven of the world's 124 most commonly cultivated crops are animal pollinated, and insect-pollinated forage plants such as alfalfa and clover provide feed for livestock. Roughly thirty-five percent of global crop production is dependent on pollination by animals (Klein et al. 2006). Pollinators also sustain wildland plant communities that provide food and shelter for myriad other wildlife. As one of the most widespread and important ecosystem services in terrestrial environments, plant pollination by insects is essential to human health, global food webs, and protection of biodiversity.

Despite the recognized importance of pollination services, there is a growing body of evidence that suggests pollinators are at risk. In the United States, the National Research Council (2006) reported that both managed honey bee colonies and wild pollinators showed significant declines. The causes of decline are difficult to pinpoint, but loss of floral diversity and habitat due to increasing urbanization, expansion of intensive agriculture, invasive plants, widespread use of pesticides, climate change, and disease and parasites have all had a negative impact on pollinator populations (National Research Council 2006). As pressure on pollinators increases from human activities and other factors, undeveloped habitat and natural areas can play a substantial role as long-term refugia for these animals.

Pollinators and Their Importance

Importance of Natural Areas for Native Pollinators and Agriculture

Native pollinators clearly help with crop pollination, yet many agricultural areas lack the habitat necessary to support native pollinators. The role that natural habitat within the agricultural landscape plays in providing crop pollination services is increasingly well understood. Proximity to natural or seminatural land is often an important predictor of pollinator diversity in cropland (Bergman et al. 2004; Kremen et al. 2004; Morandin & Winston 2006; Hendrickx et al. 2007; Winfree et al. 2007b). For agricultural areas that have lost native pollinators due to habitat modification or pesticide treatments, adjacent natural areas provide two valuable benefits. First, they are a source of pollinators for crop pollination (Kremen et al. 2004). Second, they act as refugia for pollinators that can recolonize degraded agricultural areas (Ockinger & Smith 2007).

Along with on-farm habitat, nearby natural areas are integral to maintaining long-term populations of native pollinators in agricultural landscapes; however, it is important that the management of these natural areas takes native pollinators into account.

Importance of Pollinators to Natural Areas

By aiding in wildland food production, helping with nutrient cycling, and as direct prey, pollinators are important in wildlife food webs. For example, many migratory songbirds require a diet of berries, fruits, and seeds from insect-pollinated plants. Additionally, pollinator larvae are an important component of the diet of many young birds (Buehler et al. 2002). Summerville and Crist (2002) found that forest moths play important functional roles as selective herbivores, pollinators, detritivores, and prey for migratory songbirds. Belfrage et al. (2005) demonstrated that butterfly diversity was a good predictor of bird abundance and diversity, apparently due to a shared requirement for a complex plant community.

Pollinator insects are a diverse component of the wildlife of natural areas. They include butterflies and moths (Lepidoptera), bees and wasps (Hymenoptera), beetles (Coleoptera), and flies (Diptera). There are tens of thousands of pollinator species worldwide representing these different taxonomic groups. Bees alone account for approximately 20,000 of the pollinating species worldwide (Michener 2000), with an estimated 4,000 species in the United States (Winfree et al. 2007a).

Pollinators perform such a range of ecological services in natural ecosystems that they are clearly a keystone group in nearly all terrestrial ecosystems, necessary for plant reproduction and in forming the basis of an energy-rich food web (Kearns et al. 1998).

Bees and other pollinator insects are not only important for natural areas, but also bring great benefits to nearby farms and gardens. Photograph of mining bee (genus *Andrena*) by Bruce Newhouse.

Habitat Needs of Pollinator Insects

Using pollinator conservation as a framework for managing natural areas will result in diverse plant communities and excellent habitat for all types of wildlife. In managing for insect pollinators, the first step is to understand the habitat needs of bees, butterflies, moths, and other species. These needs can be divided into two main categories: a diversity of native flowers available throughout the season, and egg-laying or nesting sites. Land managers can play a key role in protecting and enhancing pollinator habitat through the careful application of ecosystem management tools. Moreover, they can provide nesting materials for bees, and where appropriate, can increase floral resources through revegetation, as well as provide hostplants for butterflies or moths.

Diversity of native flowers. Flowering plants that benefit from insect pollination produce energy-rich nectar and nutrient-rich pollen to attract pollinators. While foraging for these, insects unwittingly transfer pollen grains within individual flowers, among flowers on the same plant, and between flowers on plants in the same general area, fertilizing the flowers and increasing genetic outcrossing of the species. Forage resources are necessary throughout a pollinator's adult life, and most species benefit from a succession of diverse blooming plants that provide adequate forage (Bowers 1985). A diverse community of insect pollinators, therefore, requires a diversity of native flowers (Dramstad & Fry 1995; Holzschuh et al. 2007).

Nesting and egg-laying resources. In addition to food, insect pollinators require egg-laying sites. For example, butterflies and moths require the appropriate hostplants for laying eggs and for their larvae to eat. The majority of bee species nest in the ground, digging narrow tunnels that lead to a small number of brood cells. Most of the remaining bee species occupy existing tunnels in large, dead, woody vegetation, though some do chew out the center of pithy twigs (Michener 2000). Bumble bees and honey bees are the main exception to this. Bumble bees require a small cavity such as an abandoned rodent nest for their colony (Kearns & Thomson 2001), and feral honey bees usually occupy large cavities, such as a hollow tree (O'Toole & Raw 1999). Some wood-nesting species also need materials such as mud, leaf parts, or tree resin to construct brood cells in their nests (O'Toole & Raw 1999). It is also important that nest sites are close enough to sources of nectar and pollen (Cane 2001).

Generalist and specialist species. The diverse habitat requirements suggested above are most appropriate for conserving generalist pollinator species, those species that can forage from a wide range of plant sources. In contrast, specialist pollinator species use limited sources of nectar and pollen, or have specific hostplants for their young. Some studies have found that management techniques that emphasize the broad habitat requirements of pollinators may preferentially select for generalist species, while ignoring the more specific requirements of specialist species (Swengel 1996; Swengel 1998; Winfree et al. 2007a).

HABITAT MANAGEMENT: GENERAL CONSIDERATIONS

Each of the techniques considered in this primer—grazing, fire, mowing, herbicides, and insecticides—can be used to manage habitat to benefit pollinators. Each can also have damaging, at times severe, impacts on pollinators if they are not used carefully. There's no single management plan that can provide ideal habitat for all pollinator taxa, but there are some general considerations that apply to all situations.

As with any management activity, biological inventories should be done to first identify important plant resources and pollinator habitat. Inventories should pay close attention to occurrences of rare or specialist pollinator species and their life cycle and habitat requirements. In some cases, specialist species, especially those with limited distributions, will become the priority consideration in planning management to ensure that they receive adequate protection.

In all of these management techniques, it is important to leave some patches untreated. Mowing or burning the entire habitat, for example, could severely impact pollinators and leave them with limited opportunities to recolonize the site. It is generally better to treat separate parts of the site in a multi-year cycle, retaining refugia from which pollinators can spread.

GRAZING

Livestock grazing in natural areas is a common practice throughout the United States. While unmanaged grazing can damage ecosystems (Bilotta & Brazier 2007), there is evidence that carefully managed grazing not only minimizes negative impacts but can provide positive benefits to floral resources in some rangeland settings, especially where shorter flowering plants are suppressed by taller grasses and buildup of thatch. Like many of the management tools discussed in this briefing, there is an ecological cost to introducing grazing into a natural system, especially in areas where herbivory by large ungulates did not occur. In some sites, it is entirely unsuited for protecting pollinators, while in other cases it can be a useful tool. For grazing management to be used effectively, the correct combination of timing, intensity, and duration of grazing, and class of livestock must be found that is best suited for the site. Finding the ideal permutation is not easy, and relies on an in-depth knowledge of the local ecosystem along with well-developed livestock management skills. Developing a com-

While the ecological impact of overgrazing can be severe, moderate levels of rotational grazing may provide some positive benefits. Photograph by Dr. Lloyd Glenn Ingles, California Academy of Sciences.

prehensive grazing and natural resource plan that includes pollinator conservation practices as one of its goals will help protect key communities of both plants and pollinators.

Livestock can greatly alter the structure, diversity, and growth habits of a plant community, which in turn can affect the associated insect community (Kruess & Tscharntke 2002). For example, it has been shown that uncontrolled sheep grazing in mountain meadows removed enough flowering plants to eliminate bumble bees from study sites (Hatfield & LeBuhn 2007). Sugden (1985) hypothesized that sheep grazing harms pollinator habitat in four ways: destruction of potential nest sites, destruction of existing nests and contents, direct trampling of adult bees, and removal of food resources.

In Arizona, Debano (2006) conducted one of the few studies focused explicitly on the impacts of domestic livestock grazing on invertebrate communities in an area that had not been grazed historically. The results clearly show that invertebrate species richness, abundance, and diversity were greater in ungrazed sites. The author suggested that since insects in the Southwest had not evolved in the presence of buffalo or other large ungulates, they had not developed grazing pressure adaptations, which made them more susceptible to being affected by the presence of cattle.

Other research shows that managed grazing can benefit insect communities by managing invasive plants and allowing spring- and summer-blooming flowers to grow. Controlled grazing has been shown to help maintain an open, herbaceous-dominated plant community that is capable of supporting a wide diversity of butterflies and other pollinators (Smallidge & Leopold 1997).

Management Considerations of Grazing: Timing, Duration, and Intensity

A diverse pollinator population requires adequate nectar and pollen sources from early spring to early fall, which makes seasonal timing a key consideration for an effective grazing plan. Ideally, management should be adjusted as needed to maintain the majority of the floral resources in an area throughout the seasons. Grazing during periods when floral resources are already scarce (e.g., mid summer, though this varies between regions) may result in insufficient forage available for pollinators such as bumble bees which, in some areas, forage into late September (Carvell 2002). Likewise, grazing during spring when butterfly larvae are active on hostplants can result in larval mortality or remove important vegetation and nectar resources (Smallidge & Leopold 1997). The most effective time to graze varies from site to site, but would generally be after the majority of the floral resources have died back, or when many pollinators are in diapause (a state of dormancy) or have successfully laid eggs. This is usually in late summer and fall.

With pollinator conservation as a goal, grazing intensity and duration are also important to consider. Intensive grazing using high livestock numbers has been shown to be detrimental. However, moderate to light stocking levels with herds rotated through the management area to create a mosaic of grazing stages can be a useful method for moderating succession in a targeted vegetation community. The timing and frequency of rotation depends on both the size and type of the herd and the size of the grazed area (Schtickzelle et al. 2007). Generally speaking, grazing periods should be short, with comparatively long recovery periods for the habitat.

FIRE

Due to the importance of fire in many native ecosystems, prescribed burning is a commonly used management tool. Understanding how insects, including pollinators, respond to fire is integral to designing a fire management strategy that protects pollinators.

Many studies have found a negative or mixed response of invertebrates to fire. In a study that examined arthropods in prairies of the American Midwest, Harper et al. (2000) found that overall species richness and the abundance of all but one of the arthropod species measured decreased in burned sites. Their results suggest that burning a small habitat fragment in its entirety could risk extirpating some species because of limited recolonization from adjacent habitat.

Reviewing the literature associated with the effects of various management techniques on insects, Swengel (2001) found that fire is more detrimental than grazing, mowing, or haying. Due to the loss of more than 99 percent of the native tall-grass prairie, managing the existing remnants based on historical fire disturbance regimes may not be appropriate. Instead, Swengel advocates an approach based on individual site characteristics and assessment of how the plants and insects at that site will respond to fire.

Many other studies have found that fire benefits insect communities. Hartley et al. (2007) found that fire was an excellent management tool in prairies for decreasing woody plants and simultaneously encouraging higher arthropod diversity. The authors suggested, however, that recolonization of the burned plots from nearby refugia is an important factor in the recovery of insect populations.

In researching prescribed burns in western forests, Huntzinger (2003) found that there was greater butterfly species richness in areas where fire had been reintroduced. The burns created large sunlit openings in the forest canopy that were favorable for herbaceous plant growth, which in

Fire can be an important management tool for managing or restoring native prairies. Photograph courtesy of Jeff Vanuga/USDA-NRCS.

turn encouraged butterflies. The author recommends a cautious approach to prescribed burning to ensure that a range of habitat heterogeneity is maintained or restored.

Management Considerations of Fire: Scale and Refugia

Prescribed burning as a management tool is a two-edged sword. It clearly has a role to play in long-term maintenance of pollinator habitat, but can have catastrophic impacts on pollinator populations. To avoid undue loss of insects, a number of considerations should be integrated into fire management protocols.

A single prescribed fire should not burn an entire area of pollinator habitat. A program of rotational burning in which small sections—30 percent of a site or less—are burned every few years will ensure adequate colonization potential and refugia for insects. In addition, as a fire moves through an area, skips—small, unburned patches—should be left intact as potential micro-refuges. Periods between managed burns over the same patch should be conservative. Based on a variety of studies cited above, it appears that three to ten years allows adequate recovery of pollinator populations, depending on the ecosystem and specific management goals.

Unless the objective for a prescribed fire is for brush or tree removal, (e.g., pinyon-juniper, chamise, or mesquite), high-intensity (hot) fires should be avoided. Low-intensity prescribed burns conducted early or late in the day, or from late fall to early spring, are not only preferable for pollinators but also reduce impacts on other wildlife species such as reptiles and ground nesting birds.

Mowing

Mowing is commonly used in areas where site access and topography permit equipment access, such as road margins and powerline corridors, and is often used in place of grazing or fire to manage vegetation. Like grazing, mowing can alter grassland succession and species composition by suppressing the growth of woody vegetation (Forrester et al. 2005). Mowing can have a significant impact on insects through direct insect mortality, particularly for egg or larval stages that can't avoid the mower (Di Giulio et al. 2001). Mowing also creates a sward of uniform height and may destroy smaller topographical features—such as grass tussocks (Morris 2000)—when care is not taken to avoid these features or the mower height is too low. Such features provide structural diversity to the habitat and offer potential nesting sites for pollinators such as bumble bees.

Yet, there are some instances when mowing is beneficial for pollinators. In a large-scale survey of prairie and barrens butterfly species, Swengel (1998) found that mowing benefited specialist butterflies.

Management Considerations of Mowing: Technique, Timing, and Scale

The differences between an ultimately beneficial mowing regime and a detrimental one are technique, timing, and scale. Because mowing can completely remove floral resources from the treated area, it should generally not be conducted when flowers are in bloom. An exception to this would be in a weed management program where there is a narrow window of opportunity for optimum control of the target species. Wherever possible, management areas should be mowed during seasons when flowers have died back or are dormant, such as in fall or winter (Munguira & Thomas 1992). Mowing at these times will also reduce disruption to nesting bumble bees.

To minimize these effects and allow sufficient space and time for pollinator populations to recover, mowing a mosaic of patches over several years is better than mowing an entire site; no single area should be mowed more than once a year (Di Giulio et al. 2001). If weed management is the short-term objective, it may be necessary to mow more frequently. In this case, try to limit mowing only to patches of weeds. As with all management, carefully consider the impact of mowing on the life cycle of known rare or specialist species in the management area. Other techniques that will benefit pollinators as well as other terrestrial wildlife are: use a flushing bar on mower/swather, use a high minimum mower/swather height (twelve to sixteen inches), use reduced mower speed (less than eight miles per hour), and avoid mowing at night (Green 2007).

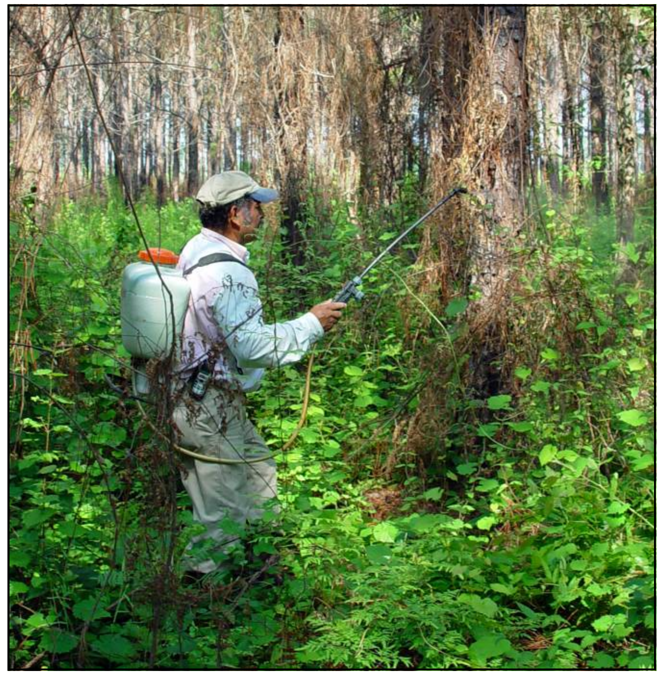
HERBICIDES

Herbicides are used to manage vegetation structure and composition, especially in controlling invasive plants, and thinning of small trees and shrubs (Miller & Miller 2004). When applied with care, herbicides can be a useful management tool. However, they can also dramatically change plant communities and decrease the usability of habitat for pollinators. For example, broadcast applications of nonselective herbicides can indiscriminately reduce important floral resources (Smallidge & Leopold 1997), leading to a decline in pollinator reproductive success and survival rates.

Management Considerations of Herbicides: Application Method and Active Ingredients

To avoid herbicide damage to nontarget plants and associated pollinators, some simple precautions should be taken. In general, avoid broadcast spraying or pellet dispersal because large numbers of larval hostplants or adult forage plants could be destroyed. Instead, spot treat with a backpack sprayer, weed wipe, or similarly well-targeted technique, allowing for selective control of undesirable plants while avoiding nontarget species. In at least one study, targeted spraying, combined with mechanical removal of larger shrubs, was found to be effective in maintaining butterfly habitat. At the same time, long-term management costs were reduced because fewer visits were required to suppress undesirable vegetation (Russell et al. 2005).

Herbicide applications should be specific enough to avoid spraying nontarget forage plants and hostplants.



Wherever herbicides or insecticides are applied, use the most targeted method possible. Photograph by Chris Evans, River to River CWMA; Bugwood.org.

INSECTICIDES

Insecticides can severely impact pollinator populations. Nevertheless, insecticides are widely used in natural areas throughout the United States to control both native and nonnative species. Many forestry insecticides have been found to have lethal or sublethal effects on native pollinators (Helson et al. 1994), and broad-spectrum insecticides used for grasshopper control in rangelands impact nontarget insects (Alston & Tepedino 2000). On farms, overspray and drift of insecticides can also affect nontarget organisms in field borders (Çilgi & Jepson 1995) or adjacent natural areas.

Management Considerations of Insecticides: Application Method, Product Formulation, and Timing

In situations where insecticides must be used, there are a number of things that can be done to minimize negative effects on native pollinators (Riedl et al. 2006).

The easiest and simplest way to avoid large pollinator die-offs as a result of insecticide application is to completely avoid treatment of areas that have flowers in bloom. Because pollinators utilize pollen and nectar as a food source, often exclusively, they will be active primarily in and around areas where flowers are abundant (Johansen & Mayer 1990). By avoiding applications in blooming areas, the risk to pollinators will be reduced, but not eliminated. Pollinators often travel through or complete some part of their reproductive process in areas where there are no blooms. For example, leafcutter bees harvest small leaf pieces to construct their nests and can be exposed to insecticide residues on contaminated foliage, butterfly caterpillars will continue to feed on contaminated leaves, and many bees nest in the ground where they may be oversprayed.

Another key method for reducing insecticide effects on native pollinators is to choose the insecticide formulation and application method that is the least harmful. Generally, dusts and microencapsulated insecticides are the most dangerous formulations for bees, and aerial spraying is the most harmful method of application (Riedl et al. 2006). Dusts are difficult to control, can easily be blown out of the target area, and readily adhere to the small hairs that cover the bodies of pollinators such as bees. Micro-encapsulated insecticides are of a similar size and electrostatic charge as pollen grains, making them easily ingested or transported back to the nest by foraging insects. Both dusts and microcapsules are collected along with pollen and used to provision brood, which can result in lethal or sublethal effects on larvae in the nest (Johansen & Mayer 1990; MacKenzie 1993). In comparison, sprayed solutions and large granules are not as readily incorporated into the foraging of pollinators, and negative effects that do occur are more likely to be limited to the adult bee. Aerial spraying almost always results in some degree of unintended drift into nontarget areas. Methods that increase the accuracy of targeted application are recommended, such as ground application and coarse sprays (Zhong et al. 2004).

Those applying insecticide should be aware of butterfly hostplants in the management area and avoid spraying on or around them. If a managed area is known to host rare or specialist pollinators, ensure that adequately buffered habitat refugia are available during and after insecticide application.

Pollinators are a vital component of our ecosystems. Planning management with them in mind will help create a healthy environment. Photograph of bumble bee (genus *Bombus*) by Mace Vaughan.

For More Information

To learn more about providing habitat for pollinators, please see our *Pollinator Conservation Handbook*. In addition, check the publications page of our website (www.xerces.org) for detailed guidelines for wildland managers, as well as guidelines for restoring and creating pollinator habitat on farms, parks, and golf courses.

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