# FARMING FOR BEES

## Guidelines for Providing Native Bee Habitat on Farms

Mace Vaughan, Jennifer Hopwood, Eric Lee-Mäder, Matthew Shepherd,
Claire Kremen, Anne Stine, and Scott Hoffman Black

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Oregon • California • Minnesota • Nebraska
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THE XERCES SOCIETY
FOR INVERTEBRATE CONSERVATION

Protecting the life that sustains us

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

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**Acknowledgments**
We thank the Alice C. Tyler Perpetual Trust, Audrey & J.J. Martindale Foundation, Columbia Foundation, Cascadian Farm, CS Fund, Ceres Trust, Cinco, Clif Bar Family Foundation, Disney Worldwide Conservation Fund, The Dudley Foundation, Edward Gorey Charitable Trust, The Elizabeth Ordway Dunn Foundation, Endangered Species Chocolate LLC, Gaia Fund, General Mills, Irwin Andrew Porter Foundation, Richard & Rhoda Goldman Fund, Organic Farming Research Foundation, Panta Rhea Foundation, Sarah K. de Coizart Article TENTH Perpetual Charitable Trust, Swimmer Family Foundation, Turner Foundation, Inc., the USDA Natural Resources Conservation Service, The White Pine Fund, Whole Foods Market and their vendors, Whole Systems Foundation, and Xerces Society members for their generous financial support that led to the production of these guidelines.

Appreciation goes to our fantastic group of farmer-partners for helping to build upon our experience, and for graciously allowing us to highlight their great conservation work in case studies and photos, including Vilicus Farms, East Multnomah Soil and Water Conservation District's Headwaters Farm, the Kerr Center, the Muir Glen Organic team at General Mills, Brian and Rhoda Gibler, DeLano Farm, Hedgerow Farms, Inc., Tadlock Farms, Sturm Berry Farm, the University of California–Davis Sustainable Agriculture Research Facility, Whitted Bowers Farm, Chet Halunen at Standish Bogs, and Omeg Orchards.

We also thank the following contributors who helped by reviewing early drafts of these guidelines:
Robbin Thorp, University of California–Davis; and Sarina Jepsen and Katharina Ullmann, the Xerces Society. We also would like to thank all of the scientists conducting field research on crop pollination by native bees. Without the support and hard work of these scientists and reviewers, this guide would not have been possible.

Editing: Kara West, Sara Morris, and Matthew Shepherd. Layout: Sara Morris.

Printing: Print Results, Portland, OR.

**Photographs**
**Covers:** *front*—pollinator planting adjacent to blueberry farm (photograph by Don Keirstead, New Hampshire NRCS); *back*—bumble bee covered with pollen (photograph by Nancy Adamson, The Xerces Society).



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**Fourth Edition (revised)**
First published in 2004. The second edition was published in July 2007, and the third edition was published in December 2011. This fourth edition revised reprint was published in January 2015.

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## APPENDICES

# 1

# Introduction

Animals pollinate roughly 35% of all crops grown in the world. More than 75% of the world's 115 principal crop species are dependent on or benefit from animal pollination, and these insect-pollinated crops provide nutrients essential to human health. In addition to improving the yield of most crop species, recent research demonstrates that pollinators such as bees also improve the nutritional value and commercial quality.

In North America, bees were responsible for roughly $20 billion in agricultural production in 2000. Most large-scale crops are pollinated by managed hives of the European honey bee (*Apis mellifera*). However, the number of managed honey bee hives is declining in the United States due to pests, diseases, aggressive strains of honey bees, reduced sources of pollen and nectar, pesticide exposure, and Colony Collapse Disorder, highlighting the risks involved in relying on a single insect to pollinate so much of our food supply.

In 2006, the National Academy of Sciences published *Status of Pollinators in North America*. The report highlights the decline of both honey bees and wild native bees across North America, the causes and consequences of this decline, and makes recommendations on conservation steps that can be taken to slow or reverse pollinator losses. These *Farming for Bees* guidelines were highlighted in the report as an important tool for pollinator conservation and increasing populations of crop-pollinating native bees.

In the past, native bees and feral honey bees could meet all of a farmer's pollination needs for orchards, berry patches, squash and melons, vegetable seed, sunflowers, and other insect-pollinated crops. These farms were relatively small and close to areas of natural habitat that harbored adequate numbers of

### Value of Native Bees to Agriculture

- Native bees pollinated approximately $3 billion of crops in the year 2000.
- There are approximately 4,000 species of native bees in North America, hundreds of which contribute significantly to the pollination of farm crops.
- Even when honey bees are present in fields, native bees contribute significantly to crop pollination.
- When honey bees are in short supply, native bees can act as an insurance policy when habitat is present.
- Habitat installed on farms to support wild bees can increase crop pollination and yield, and thus farm profits, with time.
- A diverse bee community improves crop pollination services and provides more stable pollination in variable weather conditions.

### Native Bees Compared to Honey Bees

- Native bees pollinate apples, cherries, squash, watermelon, blueberries, cranberries, raspberries, and tomatoes far more effectively than honey bees on a bee-per-bee basis.
- Many native bee species forage earlier or later in the day than honey bees.
- Native bees will often visit flowers in wet, cloudy, or cool conditions when honey bees remain in the hive.
- Direct interactions between native bees and honey bees on flowers can improve the effectiveness of honey bees as pollinators of hybrid seed crops by causing them to move more frequently between rows of male and female plants.
- Even without interactions on flowers, the presence of wild bees and managed blue orchard bees increases the effectiveness of honey bees in almond orchards by increasing their inter-row movement
- Honey bee crop pollination is not a complete substitute for the pollination services provided by a diverse community of wild bees.

pollinators to accomplish the task that now requires imported colonies of honey bees. Nearby natural areas also served as a ready source of new pollinators that could re-colonize farms and provide pollination services if insecticide applications killed resident bees.

Today, however, many agricultural landscapes are much more extensive and lack sufficient habitat to support native pollinators. In spite of this reduction in areas of habitat, the value of the pollination services that native bees provide in the United States is estimated to be worth about $3 billion per year. Research conducted across North America further demonstrates that native bees still play an important role in crop pollination, so long as landscapes around farms supply forage and nest sites.

The purpose of these guidelines is to provide information about native bees and their habitat requirements so that farmers can manage the land around their fields to provide the greatest advantage for these crop pollinators. These guidelines will help growers and conservationists:

- understand how simple changes to farm practices can benefit native pollinators and farm productivity;
- protect, enhance, or restore habitat to increase the ability of farmlands to support these bees; and
- ultimately increase a grower's reliance upon native bees for crop pollination.

Making small changes to increase the number of native pollinators on a farm does not require a lot of work. Subtle changes in farm practices can involve identifying and protecting nesting sites and forage, choosing cover crop species that provide abundant pollen and nectar, allowing crops to go to flower before plowing them under, or changing how pesticides are applied in order to have the least negative impact on bees.

Farmers with more time and interest can create additional pollinator habitat in unproductive areas on the farm, or they can fine-tune the design of conservation buffers, such as hedgerows or grassed waterways, to provide maximum benefit for crop-pollinating native bees. For example, semi-bare, untilled ground or wooden nest blocks can be added to existing wildlife habitat, hedgerows can be supplemented with a wide variety of wildflowers and shrubs that provide bloom throughout the growing season, or a pesticide-free buffer zone can be maintained around field edges.

Finally, managing marginal areas of a farm for native bees should not be confused with beekeeping. There are no hives, no need for special safety equipment, and no reason to handle any bees. In addition, most of these valuable pollinators do not sting!

Native mining bee visiting a highbush blueberry. Blueberries, and their close relatives cranberries, benefit from buzz pollination, a service only native bees can provide. (Photograph by Nancy Adamson, The Xerces Society.)

# 2

# What Are Native Bees?

North America is home to about 4,000 species of native bees, most of which go overlooked. These insects are not the familiar European honey bee, nor are they wasps or other aggressive stinging insects.

Native bees come in a wide range of sizes and colors, from tiny sweat bees less than a ¼″ long to bumble and carpenter bees bigger than 1″. While some of these species may look "bee-like", with hairy stripes of yellow, white, or black, they also may be dark brown, black, or metallic green or blue, with stripes of red, white, orange, yellow, or even mother-of-pearl. Many look like flying ants or flies. Most are solitary, with each female creating and provisioning her own nest without the help of sister worker bees. And, most are unlikely to sting.

About 70% of native bees nest in the ground and, in most cases, a solitary female excavates her own nest tunnel. From this tunnel, the bee digs a series of underground brood cells, into which she places a mixture of pollen and nectar and lays an egg.

Most other bees nest in narrow tunnels in wood, usually pre-existing holes such as those made by beetle larvae, or in the center of pithy twigs. Females of these wood-nesting bees create a line of brood cells, often using materials such as leaf pieces or mud as partitions between cells. Once the nest is complete, the solitary female generally dies. Her offspring will remain in the nest for about 11 months, passing through the egg, larva, and pupa stages before emerging as an adult to renew the cycle the next year.

Bumble bees are the most noticeable social bees in the United States. There are about 45 species. Bumble bees nest in small insulated cavities, such as abandoned rodent burrows, that are found under rocks or tussocks of grass. Depending upon the species, their colonies may have up to several hundred worker bees by mid-summer.

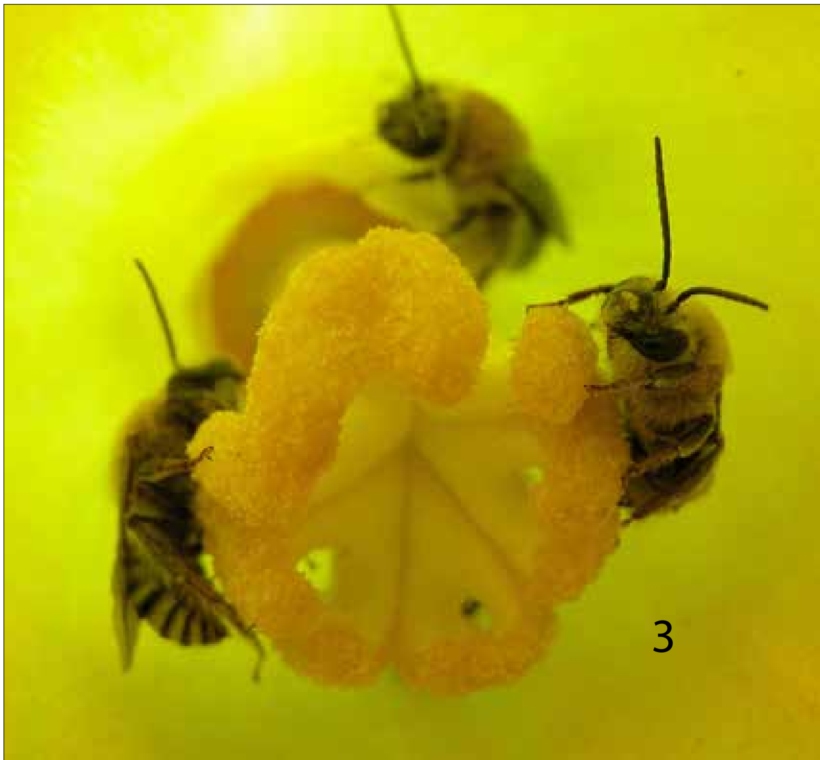
### Solitary or Social?

Asked to think of a bee nest, many people picture the hexagonal wax comb and humming activity of a honey bee hive, created by the shared labor of thousands of workers and containing enough stored honey to feed the colony throughout winter.

The nests of native bees are quite different. Most of the 4,000 species of native bees in North America are solitary. Each female constructs and supplies her own nest, which consists of a narrow tunnel and a few brood cells stocked with nectar and pollen. She lives only a few weeks as an adult and dies after her nest is completed.

Bumble bees are social bees that live in a colony and share the labor of foraging and rearing brood. But, unlike honey bee nests, most bumble bee nests are a random-looking cluster of ball-shaped brood cells and waxy pots, and are occupied by only a few dozen to a few hundred bees. Bumble bees store only a few days's supply of nectar, and the colony does not survive beyond the fall.

The life cycle of squash bees is closely tied to their host plant. Here, three males wait for females to arrive in a squash blossom. (Photograph by Nancy Adamson, The Xerces Society.)



Except for bumble bees and many sweat bees, most native bees are solitary. However, these solitary bees may occur in great numbers over a patch of ground where many females construct and provision their individual nests close together.

Bees's common names often reflect their nest-building habits: miner, carpenter, leafcutter, mason, plasterer, or carder. Other names depict behavioral traits. For example, bumble bees make a loud humming noise while flying, cuckoo bees lay eggs in other bees' nests, and sweat bees like to drink salty perspiration.

One key to recognizing bees is noticing their behavior and comparing it with that of other insects. Bees collect only pollen and nectar to feed their young. Any insect that looks like a bee, wasp, or fly, with large quantities of pollen stored on its legs or body, is likely one of our native bees.

Wasps, on the other hand, are predators in search of insect or spider prey to feed their young, and nectar to fuel their flight. They typically have fewer hairs and a more pointed abdomen. Some flies also look like bees. Again, they will never have pollen packed onto their legs. These bee-like flies often will hover in the air around flowers, without moving, before quickly dashing off—a behavior seldom seen in true bees.

### Yellowjacket Wasps Are Not Bees

This is a yellowjacket wasp, not a bee. Notice its relative lack of hair and very pointed abdomen. Most native bees are unlikely to sting. The yellowjackets and other wasps you see eating rotting fruit and hanging around picnics are not bees, nor are they significant crop pollinators. (Photograph by Whitney Cranshaw, Colorado State University, Bugwood.org.)

For more details about the life cycle and natural history of the various native bees, see Appendix A or pick up a copy of *Attracting Native Pollinators*, *Bees of the World*, or *Bee Pollinators in Your Garden*. (See Appendix D for complete references.)

Named for their nest-building habits, leafcutter bees use pieces of leaves and flower petals to seal their nests. Unlike many other groups of bees, leafcutters carry pollen on their abdomen rather than on their back legs. (Photograph by Mace Vaughan, The Xerces Society.)

## Some of the Many Crop-Visiting Bees

Bees come in all sizes and colors, from tiny to large and from black to metallic green. Some bees that you may see on crops include (clockwise from top left) bumble bees[1]; honey bees[2]; small carpenter bees[3]; green sweat bees[4]; leafcutter bees[5]; and squash bees[6].

(Photographs by: Mace Vaughan, The Xerces Society[1, 2]; Nancy Adamson[3], The Xerces Society; Rollin Coville[4, 5, 6].)

Sunflower bee on plains coreopsis. (Photograph by Jennifer Hopwood, The Xerces Society.)

# 3

# Why Farm for Native Bees?

Growers should consider the needs of native bees in their farm management and on-farm conservation practices because these insects provide a helpful role in crop pollination, increasing yields and farm profit. They also can provide an insurance policy if honey bees become harder to acquire, or continue to increase in cost. In this chapter, we go into more depth about other reasons we should protect or provide habitat for native bees.

## Native Bees Are Very Efficient

Many species of native bee are much more effective than honey bees at pollinating flowers on a bee-per-bee basis. For example, only 250 female orchard mason bees (genus *Osmia*, also called blue orchard bees) are required to effectively pollinate an acre of apples, a task that would require 1.5–2 honey bee hives—approximately 15,000–20,000 foragers.

There are many reasons for this increased efficiency. Many native bees, such as mason and bumble bees, are active in cooler and wetter conditions than honey bees. In addition, the range of foraging behaviors is more diverse in native bees than in honey bees alone. For example, nectar-foraging honey bees often never contact the anthers (pollen-producing structures) in many orchard crops, unlike orchard mason bees that forage for both pollen and nectar on every flower visit. Alfalfa flowers are shaped in a way that discourages honey bees from foraging; the alkali bee (*Nomia melanderi*) can easily forage on these flowers. Also, some native bees specialize in one type of flower. Squash bees (genus *Peponapis*), for example, primarily visit flowers from the squash plant family (the cucurbits). The females often start foraging before dawn and the males even spend the night in the flowers, which results in very effective pollination and larger fruits.

Unlike honey bees, bumble bees and many other native bees perform buzz pollination, in which the bee grabs onto a flower's stamens and vibrates her flight muscles, releasing a burst of pollen from deep pores in the anther. This behavior is highly beneficial for the cross-pollination of blueberries, cranberries, tomatoes, and peppers, among other plants. Although tomatoes do not require a pollinator to set fruit, buzz-pollination by bees results in larger, more abundant, and tastier fruit.

Honey bees also use nectar to pack the pollen into their pollen baskets for transport back to the hive. The nectar wets the pollen, decreasing its viability and holding it fast. Many native bees, in contrast, use dense patches of hair to transport dry pollen back to their nests. This dry pollen is much more available for plant pollination. Furthermore, some native bees, such as the orchard mason bee, transport pollen on the underside of their abdomens, which makes the pollen very accessible for transfer among flowers.

### How Native Bees Benefit Crops

If enough natural habitat is close by, native bees can provide all of the pollination necessary for many crops.

Native bee communities can be very diverse in crop systems. For example, 51 species of native bees have been observed visiting watermelon, sunflower, or tomato crops in California, and over 45 species of bees have been recorded pollinating berry crops in Maine and Massachusetts. In addition, 67 species of native bees visit blueberries in Nova Scotia, and 62 have been recorded visiting highbush blueberry in Michigan. Over 180 species of bees have been documented in Pennsylvania apple orchards during the growing season.

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 them to move between male and female rows more often. Only the fields abundant with both native bees and honey bees had 100% seed set.

Native bees also improve the pollination efficiency of honey bees and fruit set in almond orchards by causing honey bees to move between rows more often.

Research suggests that in the absence of imported honey bees, canola growers in Alberta, Canada, make more money from their land if 30% is left in natural habitat, rather than planting it all. This habitat supports populations of native bees close to fields, which increase bee visits and seed production in the adjacent crop.

A diverse bee community improves crop pollination services, even when honey bees are present, and provides more stable pollination in variable weather conditions.

Crop pollination by honey bees cannot fully replace the pollination services provided by a diverse community of wild bees.

Mason bees are one of the native species that can be reared easily—and even sold to home gardeners—in paper nest tubes. (Photograph by Mace Vaughan, The Xerces Society.)

# Native Bees Are Diverse and Stable

Unless they are killed by insecticides, good habitat can support strong and diverse communities of native pollinators. If a population of one bee species declines because of natural cycles of parasites or disease, other native bee species can fill the gap, thus providing a stable, reliable source of pollination.

A recent research finding provides further support that a diverse community of wild bees can provide stable crop pollination. In over 40 crops worldwide, pollination by native wild bees increased yields in all of the crops studied, while pollination by the honey bee only increased yields in 14% of those same crops. Even in crops stocked with honey bees, honey bees did not fully replace the pollination services provided by wild pollinators.

# Native Bees May Provide Additional Revenue

Habitat installed on farms to support bees can see increases in numbers of bees, as well as increases in pollination and yield of bee-pollinated crops. Meadow plantings can pay for themselves within 3–5 years, and hedgerow plantings within 5–10 years.

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, many consumers will choose farms that are "pollinator-friendly" or "wildlife-friendly" over others. In addition, if a small farm is open to tours or u-pick visits—an increasing trend, especially at vineyards and pumpkin patches—beautiful hedgerows and other habitat improvements for pollinators and wildlife can be promoted. A farm could even host a tour showcasing its resident beneficial insects.

In addition, some species of wood-nesting (also called tunnel-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.

Native plants visited by bees can have other uses as well. For example, in some areas of the United States federal and state agencies need large amounts of native seed for habitat restoration efforts. It is possible that such a market exists in your area and that native shrubs and wildflowers could be grown as a source of seeds or cuttings. This kind of crop would have the dual benefits of providing wonderful forage for native insects and another source of revenue for the farm.

## Native Bee Habitat Supports Health of Managed Bees

In addition to supporting wild bees, flower-rich habitat on farms can support honey bee health. One of the factors thought to contribute to declines and high annual losses of honey bee colonies is a lack of pollen and nectar in the landscape. Deficient nutrition can negatively impact the development and survival of honey bee colonies. Honey bees reared on multiple sources of pollen have improved immune system function, and are better equipped to survive parasitism by microsporidian parasites (*Nosema ceranae*).

## Pollinator Habitat Provides Other Benefits

In addition to the benefits of pollination, restoring or creating habitat has other ecological benefits. If placed along drainage ditches or field edges, these conservation plantings can reduce erosion of farm soils and thus save the cost of cleaning out ditches or tail-water ponds. They can also reduce the loss of irrigation water and the leaching of pesticides and fertilizers. When firmly established, native plant habitat created adjacent to fields can supplant the sources of weed seeds that were growing in those same places. Over the long-term, removing the weed seed bank will lead to a reduction in the amount of time, resources, and herbicides used to maintain these areas.

This habitat will also support other wildlife. Beneficial insects, such as parasitic wasps and predaceous beetles, will take up residence and help reduce the number of pest insects on a crop. Snags (dead standing trees) left along stream banks or field edges for tunnel-nesting bees will also provide perches and nest sites for woodpeckers and other birds. Owls and other raptors may take up residence in restored habitat* and can help control rodent populations. Protecting, enhancing, restoring, and creating habitat for pollinators will have wider benefits for both a farmer's bottom line and for wildlife.

An abundance of farewell-to-spring blossoms fill a successful and aesthetically pleasing pollinator habitat installation at this organic vegetable farm. (Photograph by Brianna Borders, The Xerces Society.)

*<u>NOTE:</u> *Due to wildlife safety concerns, we recommend attaching habitat signs to the top hole of the fence post or plugging the top hole with a bolt and nut. Alternatively, posts which do not have holes—such as solid wood stakes—should be used.*

# Case Study: Pollinator Conservation Brings Life Back to California Farm

Driving through the farm fields of Colusa County in California's Central Valley is a good way to dispel any sentimental image of farmland as lush, pastoral, and nature-rich. Massive monoculture acreages push right up against dusty roadsides, with virtually no wild plants in sight. The banks of irrigation ditches and road edges are sprayed constantly with herbicides and disked until the dry soil takes on the consistency of powdered sugar—and pests are suppressed with mammoth boom sprayers and aerial crop dusters. The only nature that takes root in the midst of these farmlands tends to be the toughest weeds like mustard and yellow star thistle, and highly mobile cropland pests like starlings and ground squirrels.

Yet, in the midst of this unlikely backdrop one company is seeking to reverse the trend and bring a little bit of nature back to Colusa County. Working with Xerces staff, Muir Glen Organic Tomatoes has launched one of the largest native plant hedgerow projects in the area. This effort not only provides pollinator habitat adjacent to one of their processing facilities near the town of Williams, but also functions as a living demonstration site and outdoor teaching facility for Muir Glen's local network of organic tomato farmers. Established in 2012, the mile-long hedgerow has restored a formerly barren and compacted dirt roadside to create a vibrant, functional, and beautiful pollinator corridor.

The background behind this success is rooted in the particular value that native bees offer to agriculture. Recognizing how research now demonstrates a strong link between buzz pollination by bumble bees and increased tomato yields, Muir Glen worked with Xerces to design a complex, highly diverse hedgerow made up of dozens of species of native shrubs, bunch grasses, and wildflowers that would attract those and other native bees with both food sources and nesting habitat.

As a first step in this process, the project team worked to immediately stop erosion and soil loss at the site by terracing the roadside slope to establish a level planting area. The slope was further stabilized with straw erosion-control waddles, and the soil was amended with compost to add back organic matter and soil microorganisms.

Then, as a second step, the team hand-planted hundreds of the larger plants along the top of the slope, including elderberry, manzanita, deergrass, California lilac, coyotebrush, California buckthorn, showy milkweed, bladderpod, bush lupine, and many others. After planting, these transplants were initially supported with a single drip irrigation line and were heavily mulched with almond shells from local orchards. Because these native plants are highly drought-adapted, irrigation only needs to be maintained for the first two years of establishment before being removed in the third year.

Finally, supplementing the larger plants along the lower part of the slope, a diverse understory of native wildflowers, like California poppy, lacy phacelia, and Bolander's sunflower, was direct-seeded to further stabilize the soil and expand the plant diversity.

To ensure that the hedgerow is functioning as intended, Muir Glen and Xerces partnered with University of California–Davis scientists to monitor the abundance and diversity of bees using the new hedgerow and to compare those findings against the abundance and diversity of bees found in the field edge areas of other farmland nearby (where hedgerows were not present). Amazingly, after only the first year, the findings were dramatic—nearly twice as many bees were found at the Muir Glen hedgerow as were found on the edges of other nearby farm fields.

Supplementing these findings, additional research conducted by scientists at University of California–Berkeley now demonstrates that, in California's Central Valley, farmers can typically expect to see a return on investment within 10 years for the costs involved in planting a hedgerow (this time can be cut in half with USDA financial assistance through Farm Bill conservation programs). That return on investment comes in the form of enhanced crop pollination, and in reduced pest damage due to the increased numbers of beneficial insects that prey upon crop pests.

While financial returns and crop yields are a key part of the equation, Muir Glen's success story runs deeper. A once-dry, desolate landscape now stands as a green, life-filled example of what is possible. This is a significant step in a new farm paradigm that will be necessary for others to follow if wild pollinators are going to have a role in agriculture, both in Colusa County and beyond.

Hundreds of plants were hand-planted as part of this hedgerow project. Irrigation was maintained for the first two years to insure proper establishment while their root systems developed. (Photograph by Eric Lee-Mäder, The Xerces Society.)

One of the benefits of landscaping with native plants is their drought tolerance. In this hedgerow, irrigation was removed after two years of establishment, even though the area was experiencing a prolonged drought. (Photograph by Jessa Kay Cruz, The Xerces Society.)

# 4

# Three Steps to Success

Because farmers have busy schedules and tight budgets, we promote a three-step approach to pollinator conservation that takes these constraints into account.

1. ***Recognize the native bees and bee habitat*** that are already on the farm.
2. ***Adapt existing farm and land management practices*** to avoid causing undue harm to the bees already present.
3. ***Provide habitat for native bees*** on and around the farm.

The first two steps require very little outlay of cash and a relatively small time commitment. The third step—developing habitat—requires more thought and effort. Our hope is that the details provided here will make this more-intensive third step straightforward for those interested in taking actions to increase the number of native pollinators on their farms. By following this approach, farmers can ease into pollinator conservation and determine whether spending additional time and money is worthwhile.

## Recognize Resources Already on the Farm

The photos in this guide and the resources listed in Appendix D provide tools for learning to recognize native bees already visiting fields. By observing the flowers in a crop, growers and conservationists likely will notice bees other than honey bees and even discover that these other species are abundant, especially if the farm is located close to natural areas.

### Finding Important Plants

After noticing the native bees that are present, learning to recognize plants that support native bees is also important. The best of these flowers will be crawling with many insects, mostly bees, and may be found in many places, including roadsides or field borders, around farm buildings, or under power lines. These flowers, which may seem like a distraction from a crop, are in fact helping local bees reproduce with greater success: the more forage available means the more offspring visiting the farm the following year. If competition with a crop is a concern, look carefully for those plants blooming before and after a crop comes into bloom. These are a critical resource for supporting the bees that forage on the target crop.

## Finding Nests


Beetle-riddled snags, such as this one, are another important nesting site for solitary bees. (Photograph by Jennifer Hopwood, The Xerces Society.)

Look for nest sites around the property. Nests of ground-nesting bees likely occur in semi-bare patches of soil in well-drained areas, often on slopes. Wood-nesting bees will be in beetle tunnels in snags or in elderberry, sumac, blackberry, or other shrubs with soft-centered twigs. Bumble bees may be nesting in old rodent burrows or under tussocks of grass. Be on the lookout everywhere.

To find ground or bumble bee nests, pay attention to bees flying low over the ground where flowers are not present, especially if they look like they are searching for something (that is, moving back and forth over a small patch of ground and occasionally landing).

Most bees are active on warm sunny days, from mid-morning through the afternoon. Some, however, may be active early in the morning (for example, squash bees), while others will continue flying late in the evening (bumble bees). One to thousands of bees may be present at a nest site, and they may be as small as a medium-sized ant (less than ¼″) to larger than a honey bee (¾″).

In the case of ground-nesting solitary bees, the nest entrance will be visible only when the adults are active, the timing of which varies from species to species. The nests that these bees occupy appear as small holes in the ground, often with piles of excavated soil around the entrance. In some cases, they may look like the entrance to an ant nest or a worm hole.

In summary, all areas left untilled—woodlots, riparian corridors, utility easements, road edges, and conservation areas, as well as unused land around fields, farm buildings, and service yards—can provide forage and nest sites. These sites have relatively undisturbed conditions that allow bee plants and nests to become well-established, and they may be enhanced with the addition of key native flowering plants and/ or nest site materials (see following chapters for details).

Bees seen entering or leaving holes in the ground are a sure sign of an active nest site. (Photograph by Mace Vaughan, The Xerces Society.)

## Adapt Existing Farm Practices

Whether or not growers or conservationists take the time to identify specific sites harboring ground-nesting bees or forage plants, farm management practices can be adjusted to take important pollinator resources into account. One important step is to minimize the risk to bees from pesticide applications. Reducing pesticide drift and creating buffer zones around a crop—for example, the outermost 20′ of a crop—will go a long way toward protecting bees nesting or foraging in field margins.

Minimizing the practice of fencerow to fencerow farming, so that crop fields retain an uncultivated, untilled field margin, will provide areas where ground nests and forage may become established.

Depending upon the cropping system and the plants raised, farmers also may consider letting plants flower whenever possible (as happens already in many cases). Allowing crops such as lettuce, arugula, radish, broccoli, potatoes, endive, kale, brussel sprouts, cilantro, basil, and forage legumes to bolt before tilling provides an additional source of forage for bees.

Staggering planting of a single crop variety or choosing multiple varieties with different flowering periods also helps support pollinators by extending the period over which flowers are available. This allows more time for populations of native bees to forage on a crop, increasing their reproductive success.

Flowers providing nectar and pollen are a necessary part of pollinator habitat. (Photograph by Jennifer Hopwood, The Xerces Society.)

Another way to support native bees and their habitat is to leave areas supporting native bees alone as much as possible. For example, sites with ground nests should be protected from tilling or insecticide applications. Rodent burrows can be left for bumble bee nests, and beetle-riddled snags should be left for mason and leafcutter bees. Sites on which good forage plants grow should be protected from disking, insecticides, and herbicides.

If good forage plants also happen to be weeds, rethink whether the need to remove the weeds outweighs the value of the pollinators these plants support. It makes sense to remove the source of noxious weeds, of course, but it is worth giving a second thought to less invasive species. Weeds also may be an important resource in dry late summer conditions, and can extend the reproductive season of the few species of native bees that produce many generations per year, like bumble bees and some sweat bees.

Native bees may also take up residence in a field. For example, squash bees are tightly connected with their cucurbit host flowers and may dig vertical tunnels in the ground near the host plants. Because the cells containing the next generation are typically concentrated 6″–12″ below the surface of the ground, plowing these nests kills most of the developing bees. Therefore, those farmers discovering squash bees living in fields of melons and squash could try setting their plows at shallower depths, ideally less than 6″, or investigate the use of no-till options.

## Provide Habitat for Pollinators on Farms

Farmers who want to take a more active role in increasing the numbers of native bees around farms can do three things to make the land more hospitable for pollinators.

- ***Increase the available foraging habitat*** to include a range of plants blooming at different times to provide nectar and pollen throughout the seasons.
- ***Create nesting sites*** by providing suitable ground conditions or tunnel-filled lumber and appropriate nesting materials. About 70% of bee species nest in the ground and 30% use tunnels bored into wood. Bumble bees—a small, but very important group of bees for crop pollination—require small cavities in which to fashion their nests.
- ***Reduce the risk to bees from the use of insecticides and herbicides***, which directly kill pollinators or the plants they rely on. Select less toxic insecticides or utilize alternative strategies to manage pest insects and minimize the use of insecticides.

The chapters that follow detail how to enhance habitat for native bees, starting with choosing sites for habitat improvements within and around the farm landscape. The next three chapters address the major constraints to populations of native bees: forage availability, nest site availability, and pesticide use. In each chapter we describe how to provide these habitat resources and/ or how specific farm management practices may be altered to reduce the impacts on crop-pollinating native bees. It is important to keep in mind that a wider range of ecological conditions on a farm will attract a greater diversity of species.

### Xerces Society Pollinator Habitat Assessment Guide

The Xerces Society developed a Pollinator Habitat Assessment Form and Guide to help farmers and conservationists assess specific habitat features on and around the farm for value to pollinators, and to evaluate and prioritize future habitat enhancements. This comprehensive planning tool is available at: http://www.xerces.org/wp-content/uploads/2009/11/PollinatorHabitatAssessment.pdf

In addition, see Appendix C for a Pollinator Habitat Checklist with potential pollinator foraging and nesting habitat features on farms.

A hedgerow of native flowering shrubs flanked by native bunch grasses offers many resources to pollinators. The fallen grass can become a haven for bumble bee nests and the shrubs provide pollen and nectar. (Photograph by Jessa Kay Cruz, The Xerces Society.)

## Case Study: Leveraging Existing Natural Areas for Blueberry Pollination in Oregon

Brian and Rhoda Giblers's blueberry farm in Eagle Creek, Oregon, resembles many mid-sized family berry farms in the region. Well-maintained rows of mature bushes stretch across several acres, surrounded by neighboring horse pastures and hayfields.

A closer look, however, reveals something not found on many farms in the area—a diverse remnant native plant community of camas, lupine, and popcorn flower all thriving within a seasonal wetland system that includes a grassy ephemeral creek bed just outside the blueberry field. Such meadows are now among the rarest plant communities in the Pacific Northwest, with most of them in western Oregon having been lost to agriculture long ago. Despite the loss of these meadow systems, they remain among the most important habitat type for pollinators in the region, and their protection can provide direct benefits to farmers of bee-pollinated crops.

Wildflower seeding in areas such as this field border can be an attractive way to provide additional pollinator resources. (Photograph by Eric Lee-Mäder, The Xerces Society.)

The existence of this native plant meadow is a testament to the Giblers's excellent land management practices, which focus aggressively on the control of invasive weeds such as Himalayan blackberry, Canada thistle, and teasel. Each of these weeds is quick to invade within blueberry rows, and once established they can be difficult to control. By constantly working to keep invasive plants under control across the farm, the Giblers have created conditions that allow the native plants to thrive. In addition to preventing weeds from growing within the blueberries, the recent arrival of spotted wing drosophila (*Drosophila suzukii*)—a major pest of berries—makes the control of blackberries even more important (to eliminate alternate food sources for the pest).

While this program of invasive plant control alone has made the Giblers's farm a rich landscape for bees, they haven't stopped there. Working in field border areas where equipment traffic is more frequent, and some disturbance is unavoidable, Brian and Rhoda have done simple broadcast seeding of low-cost native wildflowers such as California poppy, clarkia, meadowfoam, selfheal, and more. These wildflowers extend the pollen and nectar resources throughout most of the growing season.

The impact of these efforts is obvious and remarkable. On any given day in spring and summer, the Giblers's wetland meadows and field borders hum with countless native insects like yellow-faced bumble bees, green metallic sweat bees, and even grey hairstreak butterflies. The dazzling flower color that attracts these insects also makes the farm gorgeous—resulting in neighbors asking the Giblers what they are doing to encourage all of the wildflowers. Beginning with a foundation of high-value native plants, supported with invasive weed management, and supplemented with low-cost wildflowers in field edges, the Giblers demonstrate a straightforward pollinator conservation model that is within the reach of many farmers.

This pollinator habitat was enhanced by broadcast-seeding additional native wildflowers into a remnant native grass and wildflower meadow that already included camas, lupine, and other forbs. (Photographs by Eric Lee-Mäder, The Xerces Society.)

# 5

# Where to Provide Habitat

Research conducted across North America demonstrates that farms with natural areas less than a half-mile from field edges have greater numbers and diversity of native bees, as well as significantly increased pollination services from these wild bees. Here are suggestions for areas around a typical farm where pollinator habitat could be protected or restored, followed by site characteristics that are important to consider when selecting where to place habitat.

## Potential Areas for Bee Habitat on Farms

A filter strip of native wildflowers above a small stream supports many beneficial insects and helps protect water quality. (Photograph by Mace Vaughan, The Xerces Society.)

### Existing Habitat

The first place to look when thinking about enhancing or restoring pollinator habitat is the suitable habitat that already exists. For example, areas left untilled, such as woodlots, stream banks, utility easements, and conservation areas, as well as unused land around farm buildings and service areas, all can provide forage or nest sites needed by native bees. These sites have relatively stable conditions that allow bee plants and nests to become well-established, and may be enhanced with the addition of key native flowering plants and/ or nest site materials. At a minimum, simply leaving these areas alone and protecting them from pesticides creates nesting and foraging opportunities for native bees.

### Management of Existing Habitat

Sometimes existing habitat is degraded, either through the invasion of weedy species, or with encroachment of woody plants as succession moves onward. In such cases, enhancement of existing habitat may be achieved through the removal of invasive plants or the introduction of disturbance.

For example, in the Southeast, Chinese privet (*Ligustrum sinense*) invades hardwood forests and forms a dense thicket, shading out native shrubs and wildflowers that grow in the forest understory. Scientists tracking changes in plants and wildlife following privet removal noticed that the numbers of bees increased dramatically, from a modest 10 species to nearly 50 species. In another example, researchers observed similar positive changes in the pollinator community several years after removing an invasive buckthorn from fens.

Prescribed fire is a management tool used to disturb habitat and revitalize certain plant communities. In the Midwest, fire might be used to restore wildflower diversity in tallgrass prairies heavily invaded by native but aggressive Eastern red cedar trees. In the Southeast, fire and thinning can restore understory plant communities in longleaf pine forests. The Natural Resource Conservation Service (NRCS) often assists with land management and restoration. The NRCS conservation practice Restoration and Management of Rare and Declining Habitat is geared towards aiding landowners in enhancing existing habitat.

A southeastern woodland invaded by the invasive Chinese privet, before control measures were taken. (Photograph by Sudie Thomas, NRCS.)

A much more open and diverse understory within the same southeastern woodland, four years after privet removal. (Photograph by Sudie Thomas, NRCS.)

Peripheral areas along roads, field borders, and streams all can be enhanced to provide the maximum benefit to native bees. These habitat features also provide connections across the land, so that pollinators and other beneficial insects can colonize new habitat more efficiently. (Photograph by Lorraine Seymour.)

This insectary planting at DeLano Farm supports predatory and parasitoid insects in addition to providing additional resources for foraging bees. (Photograph by Jennifer Hopwood, The Xerces Society.)

## Peripheral Areas

Peripheral areas, such as field edges, fencerows, hedgerows, levees, road edges, and banks of drainage ditches, offer both nesting and foraging sites. If these areas are not tilled fencerow to fencerow, they can be relatively stable over time, which allows the soil structure and plants to mature. A well-established hedgerow or buffer planting of non-weedy native forbs, shrubs, and trees can out-compete the weeds in these strips. Simultaneously, hedgerows can serve as a source of other beneficial insects, a means of erosion control, and a barrier to drifting pesticides. Furthermore, these linear patches of habitat likely provide a corridor along which bees and other beneficial insects can migrate more quickly through the agricultural landscape.

## Insectary Plantings

Many of the plants that provide forage for predatory or parasitic insects that combat pests also provide nectar and pollen for crop-pollinating bees. Consider adding plants for bees, such as phacelia, clover, alfalfa, or canola, within these insectary plantings.

## Poor Quality or Poorly-Irrigated Land

Some of the best places around farms for creating habitat for native pollinators are the worst places for growing crops. For example, areas with the poorest soils may provide some of the best sites for ground-nesting bees, because these animals often prefer nesting in well-drained, inorganic sand and silt.

The edges or corners of irrigated fields and tail-water ponds, which do not receive enough water to support a crop, provide excellent sites for growing various forbs, shrubs, and trees. In addition, if the soil conditions are right, the soil excavated from tail-water ponds or drainage ditches can be piled to form well-drained mounds for ground nests and sites for sowing native plants.

### Orchards and Other Perennial Crops

Perennial crops, like fruit trees, berries, and grape vines, may be planted with a cover crop, such as clover, vetch, short-statured yarrow, or phacelia, that serves as a source of nectar and pollen.

A common problem faced by bees making a living in large stands of apple or cherry trees, for instance, is that the flowers of these crops bloom all at once and then are gone after only a few weeks. This short flowering period, with very little else available the rest of the year, is not conducive to supporting large populations of pollinator insects that may be active as adults before and/ or after the bloom. Therefore, by sowing a cover crop underneath these trees (perhaps one like clover that adds nitrogen to the soil), farmers can grow apples or cherries and also support large numbers of native bees that may spill out onto other fields and crops. Growing a mixed cover crop will further ensure a diverse bloom. If there are concerns about pollinators, particularly honey bees, being distracted from the fruit bloom, these cover crops may be mown when the trees are flowering.

### Farm Gardens

Flower gardens planted for their beauty or cut flowers provide yet another source of nectar and pollen for wild bees. See Chapter 6 and Appendix B for advice on choosing diverse garden flowers and lists of plants that provide great resources for pollinators.

## Site Characteristics to Consider

Once the decision is made to enhance habitat for pollinators and potential sites around the farm have been chosen, the next step is to determine which are the most appropriate for habitat improvements. Here are several issues to consider when choosing locations for the various habitat components needed by native bees.

### Distance from Fields

The average foraging distance of native bees ranges from about 50′ to upwards of a half-mile, with larger species able to fly farther. To be of greatest benefit for crop production, areas of natural habitat should be within a half-mile of an insect-pollinated crop. Ideally, potential nesting sites would be even closer (a few hundred yards), in order to increase the number of small bees reaching a crop in bloom.

It is important to balance the need for proximity of habitat to crop fields with protecting that same habitat from pesticide drift. If an area under consideration for conversion to pollinator habitat cannot be protected from pesticide drift—especially insecticides—then alternatives should be considered.

### Size of Habitat Patches

Studies in California provide evidence that around 30% of the land within a half-mile of a field should be in natural habitat in order to provide full pollination for watermelon. Similarly, studies in Canada have shown that, in the absence of honey bees, canola farmers can increase their income if 30% of their farmland is left in natural habitat.

Scientists and growers are still learning about how much habitat is needed for crop pollination by wild bees. In general, a sound strategy is to make habitat patches as large as feasible within the constraints of a farm and to create as many patches as possible. Habitat should be situated close to insect-pollinated crops and may be connected with habitat corridors. Larger areas of habitat ensure a greater likelihood that forage, nest sites, and nest building materials will be available within the bees's flight range and throughout the flight season.

## Habitat Corridors

Cultivated fields have replaced most of the natural habitat in many modern agricultural landscapes, resulting in significant distances between areas of habitat that harbor native pollinators. Continuous, permanent strips of vegetation can link these patches and potentially increase the rate at which pollinators and other wildlife colonize new areas of habitat near agricultural fields. They also may serve to grab the attention of bees flying across the landscape. These long narrow habitat features can dress up drainage ditches, fencerows, and roadsides. Increased connectivity, particularly between larger areas of natural habitat, will bring a greater overall benefit.

## Partial Habitats

When practicing pollinator conservation, growers can take advantage of sites around a farm that may be suitable for only one component of pollinator habitat. For example, forage can be planted in areas that are periodically flooded and, therefore, unsuitable for ground nests. Setting up nest blocks on the side of a barn can be an important addition to a farm, even if flowers are not located close by. Although individually these partial habitats may not provide everything that native bees need, together they can support bee populations. These partial habitats will be especially beneficial if they are within 300 yards of each other, as most tunnel-nesting bees are small and have a more limited flight range.

This pollinator hedgerow planted along a farm road is comprised of a variety of forbs and shrubs that flower from early spring through summer. (Photograph by Jessa Kay Cruz, The Xerces Society.)

## Topography

Topography has a strong influence on pollinator habitat because the slope and aspect of a site influences drainage rates, moisture levels, and sun and wind exposure. For example, south-facing slopes are usually warmer, creating better foraging conditions for sun-loving bees. South-facing slopes are also drier and thus are preferred as nest sites by ground-nesting bees. Plants on such sites, however, will dry out more quickly and need to be more drought tolerant.

Therefore, establishing or protecting forage in nearby low-lying or north-facing areas—where plants may flower later or for longer periods in the summer—may provide the additional resources needed by bees throughout the hot summer months.

## Areas Unsuitable for Agriculture

As mentioned above, sites with poor soils or areas that are poorly irrigated may result in weak crops that could be replaced with valuable pollinator habitat.

## Irrigation

Plants in most new areas of habitat will need water to become well-established, so access to established irrigation systems is an important consideration. The type and coverage of irrigation of adjacent fields also will have an impact on pollinator habitat. Areas at the periphery of irrigated fields, where there is some overspray, might be excellent sites for establishing hedgerows or other plantings. These same areas may prove to be very poor sites for ground-nesting bees, especially if flood irrigation is used. Flood irrigation covers the soil with a standing layer of water that may saturate bee nests below.

## Accessibility of Habitat Areas

All new habitat areas must be accessible for planting and maintenance. In the long term, maintenance should be minimal, but during the establishment period access is needed for weed control and irrigation.

## Location of Trees

The presence of trees has several positive effects. Trees act as a windbreak, making it easier for bees to visit flowers and to stay warm on cooler days. If the correct species are chosen, trees serve as an excellent source of nectar and pollen. In cooler regions of the country, bees may be less likely to build nests in areas that receive too much shade. In hot areas, however, shade is less likely to be a problem for nesting bees and can also be a place where farm workers rest on hot days. Trees can also serve as important landmarks for foraging bees.

# Case Study: Integrating Pollinator Habitat into Dryland Fields

Doug and Anna Crabtree of Vilicus Farms have already integrated huge, expansive wildflower buffers between their production fields. Yet, if you ask, they will tell you they are just getting started. Farming more than 1,500 acres of dryland organic field crops in northern Montana, Doug and Anna have a goal of integrating pollinator conservation areas across their entire operation.

While many of the Crabtrees's more than 15 crops, such as black emmer and einkorn wheat, do not require insect pollination, others like flax, safflower, and sunflower benefit greatly from wild bee visitation. In addition to supporting pollinators, the Crabtrees are also interested in other benefits the buffer habitat can provide, including attracting insects involved in natural pest control, reducing wind velocity for adjacent seedling crops, reducing overland surface water and sediment runoff, and capturing wind-blown weed seed before it can settle in production fields.

While the Crabtrees's wildflower buffers are clearly paying dividends today, early in the design and establishment phase there were a number of questions about just how to get high-quality native wildflower habitat established using only organic methods. Covered with crested wheatgrass, an introduced plant known for its competitive ability and hardiness in cold, dry landscapes, the field borders certainly posed a site preparation challenge. Without herbicides as an option to remove existing weeds, the Crabtrees worked with Xerces staff to design a series of replicated tillage trials to understand which cultivation strategies would be most successful at suppressing future re-growth by the crested wheatgrass and provide a clean seedbed with minimal weed competition for the native wildflowers. The trials included the use of a wide chisel plow to open up bare ground swaths between fields that could be re-seeded into, as well as the use of deep moldboard plowing to invert the entire sod layer in other field borders to create a totally barren, grass-free surface.

A bumble bee visits a phacelia blossom in a wildflower buffer at Vilicus Farms, northern Montana. (Photograph by Jennifer Hopwood, The Xerces Society.)

Planting into a non-irrigated landscape averaging less than 12" of precipitation annually, we looked to include the most drought-adapted western native species for which we could find seed sources. The seed mix included resilient perennial wildflowers such as Lewis flax, blanketflower, Maximilian sunflower, yarrow, and scarlet globemallow, as well as annual wildflowers like plains coreopsis and wild sunflower to provide immediate resources for beneficial insects and rapidly cover the soil to prevent erosion. Low-stature native cool and warm season grasses were also included, to buffer against weed invasion. The seeds were planted in late spring, immediately after plowing, and just before the area typically receives most of its rain.

With little to no re-growth by the crested wheatgrass, fast, prolific growth by the newly-established native plants, and increased pollinator activity, the field borders, particularly the borders created using the moldboard plow, have been a success so far. Complementing these wildflower areas, the Crabtrees are using extensive multi-species, flowering, cover crop rotations that build soil organic matter, disrupt pest and disease cycles, and help create corridors for beneficial species to move throughout the farm. As ecosystem-based farmers, Doug and Anna are committed to farming land that provides its own pollinators, its own pest control, and its own nutrient cycling.

Wildflower buffer supports pollinators and beneficial insects adjacent to organic crops. (Photograph by Jennifer Hopwood, The Xerces Society.)

Doug Crabtree of Vilicus Farms standing in his sunflower crop field. Sunflowers benefit from wild bee visitation, which is boosted by the Crabtrees's pollinator field borders. (Photograph by Jennifer Hopwood, The Xerces Society.)

# 6

# Creating Foraging Habitat

Providing forage for wild bees is critical for their reproductive success. When more pollen and nectar are available close to bee nest sites, female bees can forage more efficiently and lay more eggs. The ultimate result is a farm that grows an abundance of its own pollinators. Here we provide considerations on how to choose plants for pollinator habitat, gardens, and forage cover crops, and techniques to establishing foraging habitat.

## Plant Selection

To be of greatest benefit to the pollinators living around a farm, foraging habitat should contain a wide variety of plants that provide a succession of flowers throughout the growing season. The plants included in a patch or hedgerow of bee forage also should require minimal maintenance once they are established. Native plants are frequently the best choice because bees tend prefer to forage on native plants over introduced plant species. Native plants are also adapted to grow in the local climate and soils and, once established, they require little attention. However, non-invasive, non-native plants may be used when cost and/ or availability are limiting factors.

The appendices provide specific information on finding appropriate pollinator-friendly plants for restoration projects. Appendix B includes an example seed mix for a meadow planting, a regional species list for a hedgerow, and lists of cover crops and garden plants that are excellent sources of pollen and nectar for bees. Appendix D includes links to national and regional lists of plants that are important sources of forage for bees across the United States. Used with the guidelines below, and in consultation with native plant nurseries, native plant societies, or local arboretums, this information will help land managers choose regionally-appropriate plants for native bee habitat.

### Plant Diversity and Bloom Time Succession

The best bee habitat contains a diversity of flowering plants. Pollinator diversity increases with increasing plant diversity. A range of flower shapes supports more bees and other beneficial insects. Bee species vary in size and have different tongue lengths; consequently, they will feed on differently-shaped flowers. There is a rough correlation between the depth of the flower tube and the length of the tongue of the bees that use them. Some very open flowers, such as asters, have nectar and pollen that is readily accessible to insects of all sizes, including bees with short tongues. Other flowers, such as lupines and penstemons, have pollen or nectar that is harder to reach and are preferred by robust bees—such as bumble bees—that can push between the petals. Focus on selecting plants known to provide abundant forage for bees (See Appendices B and D for resources).

Foraging habitat for bees should include flowers with overlapping bloom times to provide continuous floral resources throughout the growing season. Adult bees can be seen anytime between February and November; they have longer seasons in areas with mild climates. The social bumble bees may be seen in any of these months, whereas the emergence of many solitary bees is synchronized with the flowering period of particular plants or groups of plants. Therefore, a sequence of plants—from willows in the spring to goldenrod in the fall—that provide a diversity of flowers throughout the growing season is needed to support a wide range of bee species with variable flight periods.

It is especially important to include plants that flower early in the season. Many native bees, including bumble bees and some sweat bees, produce multiple generations each year. More forage available early in the season will lead to greater reproduction and more bees in the middle and end of the year. Early forage may also induce bumble bee queens emerging from hibernation to start their nests nearby and be more successful in raising their first brood of workers.

In some regions, early blooming wildflowers are not widely available as plant material or are difficult to establish. Consider including early blooming shrubs in addition to planting wildflowers that will flower later in the spring through the fall, in order to provide season-long forage.

Diverse, blooming wildflower habitat supports bees and other beneficial insects. (Photograph by Eric Lee-Mäder, The Xerces Society.)

This diverse pollinator habitat installation, adjacent to an almond orchard on Tadlock Farms, Colusa County, California, provides forage for bees after the almond bloom in early spring. Dominant flowers in bloom are lacy phacelia, California poppy, and arroyo lupine. (Photograph by Jessa Kay Cruz, The Xerces Society.)

Many mining bees emerge early in the season, when fruit trees are in bloom. They can be excellent orchard pollinators. Here, a mining bee pollinates an apple blossom. (Photograph by Nancy Adamson, The Xerces Society.)

### Project Integrated Crop Pollination

To meet the needs of growers of pollinator-dependent specialty crops, Project Integrated Crop Pollination (ICP) is conducting research and extension nationwide on pollinator habitat enhancement and farm management practices that increase wild bees, as well as techniques for managing alternative bees for crop pollination.

ICP integrates habitat enhancement for wild bees, farm management practices to support bees, and use of diverse managed bee species into farm systems. Funding from the USDA Specialty Crops Research Initiative is supporting this team of scientists and outreach specialists. Project ICP research is also improving the use of alternative managed bees, such as bumble bees and mason bees, to increase the reliability of crop pollination. Project ICP has a strong economic and social component, and will assess how best to fit ICP strategies into different scales of crop production, as well as how best to share project results with specialty crop growers nationwide to achieve meaningful adoption. See Project ICP's website for more information: www.projecticp.org.

## Choose Plants That Complement a Particular Crop

Bees are active as adults before crops come into bloom and are still active afterwards. Therefore, plenty of forage should be on hand before and after a particular crop comes into bloom. This timing will attract bees to a farm, ensure that the local crop-pollinating bees can successfully raise many young, and offer the least competition with a focal crop.

If a farm already grows a diversity of crops, the timing of flowers produced by non-crop plants is less of a concern. The crops themselves help provide a sequence of bloom. If growing a perennial crop, such as orchards or berries, cover crops between rows may include plants like white clover that can be cut short when the crop is in flower, but then be allowed to bloom afterwards.

## Use Locally Adapted Native Plants

Local native flowering plants are usually well-adapted to the growing conditions at a specific site. They thrive with minimum attention; are good sources of nectar and pollen for native bees; and are usually not weedy. In addition, many local native bees may be adapted to gather pollen and nectar from these native plants, and research indicates that even introduced bees like honey bees often prefer to forage on native plants. Horticultural varieties and hybrids, in contrast, are not always adapted to local conditions, and some may have been bred to produce showy blooms or other traits at the expense of nectar or pollen production.

When obtaining native plants, it is best to find out where the seed came from. Some plants sold as native are not from local sources and may not survive as well as plants grown from locally-collected seeds. Other potential sources of plant materials are seeds gathered from flowers in local wildlands. This requires more work and access to natural areas, but also results in locally-appropriate plants that, in the end, may be less expensive to rear.

## Avoid Invasive Plants and Alternate Pest or Disease Hosts

Avoid plant species known to be highly invasive or weedy on the farm. These plants likely will spread and dominate other species, reduce the diversity and value of the habitat, and increase maintenance demands—both in the habitat patch and elsewhere around the farm. They also may spread beyond the farm and cause problems in neighboring natural areas. For example, many mustards provide good forage for bees and work well in orchard understories where regular mowing or spraying can manage weeds. On nearby organic or row crop farms, these same mustards can spread and be a challenging weed.

In most cases, native pollinator plants do not serve as alternate hosts for crop pests or diseases, but selected plants should be cross-referenced for specific crop pest or disease associations. Research indicates that weedy borders harbor more pests than are found in diverse native plantings. This is likely because many if not most of our roadside weeds are Eurasian species that are frequently related to many of our crops.

Rattlesnake master (foreground) and blazing star are high-quality, native floral resources for bees and other beneficial insects. (Photograph by Jennifer Hopwood, The Xerces Society.)

## Choose Appropriate Plants for the Site

The environmental conditions of the chosen habitat area will influence the choice of plants. Sun-loving prairie plants obviously will not do well if planted in the shade of trees, nor will shade-dwelling forest plants thrive in the sunny exposure of a prairie. It is harder to pay attention to the changes in soils, slope, exposure, and moisture across a site, but these also should be taken into account whenever possible. One way to address this situation is to take notes on the native plants growing wild in similar conditions nearby.

### Not Sure Which Plants Might Be Weedy or Invasive in Your Region?

Visit the USDA–NRCS PLANTS Database to find lists of noxious weeds by state, as well as a list of species that are weedy or invasive or have the potential to become problematic within the United States: https://plants.usda.gov/java/noxiousDriver#state. You might also consider checking with your county for any code restrictions on noxious weed species.

Planning 5–10 years ahead can also help guide plant choices. Consider the use of the land immediately around the habitat and how it will be affected by the size, structure, and/ or needs of the chosen plants when they are mature. For example, when planting a hedgerow next to a road, ditch, or service area, properly chosen trees and shrubs may serve as forage for pollinators and also grow to provide privacy or shelter from wind. If planting habitat between fields, shorter plants will be advantageous in that they will not compete with adjacent crops for sunlight. Pollinator habitat between fields will benefit from the adjacent irrigation; plants with greater water needs may grow better close to fields than farther away.

## Ease of Planting and Establishment

If possible, choose species that are easy to plant and establish. This information most efficiently comes from local experts in habitat restoration. Consider consulting with staff from local offices of the Natural Resource Conservation Service (NRCS), Soil and Water Conservation District (SWCD), Cooperative Extension, native plant societies, or non-profit organizations that work on habitat restoration.

While plants are being chosen, it is worth considering what existing equipment and infrastructure are in place for planting and maintenance. For example, is equipment on hand for sowing seed, which would make it easy to create a patch of flowering forbs? How would a new planting fit into a pre-existing irrigation system?

## Include Some Grasses

Although grasses do not provide nectar or high-quality pollen for foraging bees, consider including one or more species in your habitat planting. Grasses are larval host plants for some butterflies, provide potential nesting sites for bumble bee colonies, and can be overwintering habitat for bumble bee queens as well as other beneficial insects. In addition, grasses help to buffer against invasive weeds. In seed mixes, aim to include shorter-statured bunch grasses or low densities of tall grass species, in order to avoid competition with wildflowers.

# Establishing Pollinator Habitat

Flowers can be established from seeds or transplants, or a combination of both, depending on your goals for your habitat. If your planting is large, planting seeds is most the cost-effective approach. Additionally, some species are only available as seed. However, if you are looking for your habitat to provide resources as soon as possible, transplants will flower more rapidly than plants that establish from seed. Transplants also have a competitive advantage over weeds than seed and are more likely to survive drought once they are established. No matter the type plant material you select for your project, site preparation to reduce weed pressure as well as maintenance over time is critical for the success of the planting.

## Site Preparation

Before planting either seeds or transplants, site preparation is a critical step. Site preparation involves removing existing vegetation and reducing the amount of weed seed and rhizomes in the soil, in order to reduce competition and give your plants their best shot at establishment. Depending on the abundance of weeds, more than one year of site preparation may be needed.

Site preparation can be performed using several different methods. The use of broad-spectrum herbicides is a low cost and effective approach. Repeated treatments throughout the growing season may be needed to kill existing vegetation and subsequent emerging weeds. When the use of herbicides is not an option, such as on organic farms, using clear UV-stabilized plastic to solarize existing vegetation can also be effective. Mow existing vegetation, smooth the site, and lay down the plastic, burying the edges to prevent airflow underneath the plastic. Leave the plastic in place during the hottest time of the year before removing it in early fall before the weather cools dramatically. In certain regions, soil inversion using a moldboard plow may be an herbicide-free option for sites that are too large for solarization (see case study on Vilicus Farms in Montana, page 24).

After existing vegetation has been removed, soils should be smoothed and lightly packed. A rake or turf roller can be used to break up clumps in small sites, and a cultipacker or tractor-drawn roller can be used at larger sites.

## Establishing Seed

Local seed vendors can provide recommendations of how much seed you need for your site; generally recommended rates for wildflower plantings range from 40–60 seeds per square foot. You can also develop your own seed mix with certain proportions of particular species (see Appendix D for tools, such as a seed rate calculator). See Appendix B for an example seed mix. While the species may not be appropriate for your area, the general features of the list (bloom time succession, grass density, etc.) will help to serve as a starting point.

Early fall or dormant season planting of wildflower mixes is generally recommended for most regions of the county. Many perennial plant seeds need exposure to cold, damp conditions over time to successfully germinate. Although spring plantings are possible, they tend to favor establishment of grasses over wildflowers.

Seeds can be planted into a clean seedbed using a no-till native seed drill, a mechanical broadcaster, or can be broadcast by hand. Though low-tech and low-cost, broadcasting seeds by hand can be very effective. Seeds can be scattered onto the soil surface by hand, with hand operated crank seeders, or with ATV-mounted seed spreaders. Before spreading seed, mix the seed with an equal or greater volume of a bulking agent such as sawdust, coarse sand, vermiculite, or other inert material. The inert material will help distribute seeds of various sizes throughout the mix, and will provide visual feedback on where seed has been thrown. Then divide the mix into two separate batches and spread the batches onto the site in perpendicular passes to distribute the seed evenly across the site. Seed can then be pressed into the ground using a turf grass roller or cultipacker, which provides good seed-to-soil contact.

Native wildflower insectary strip for pollinators at University of California–Davis Sustainable Agriculture Research Facility, Yolo County. Dominant flowers in bloom are golden lupine and California phacelia. (Photograph by Jessa Kay Cruz, The Xerces Society.)

## Establishing Transplants

After site preparation, woody or herbaceous transplants can be installed at any time the ground can be worked. Most woody shrubs can be spaced 4′–10′ apart (depending upon size at maturity), with most herbaceous plants spaced closer to 2′–3′ apart. It is helpful to measure the planting areas prior to purchasing transplants, and to stage the transplants in the planting area prior to installing them in the ground.

If transplanting an herbaceous species, dig a hole the same depth as the container and place the plant within the hole so that the roots and a small portion of the stem will be covered by soil. When planting trees and shrubs, place plants within holes so that the base of the plant is slightly above the soil. Mulching is recommended to reduce weed competition and to retain moisture during the establishment phase. Recommended materials include wood chips, bark dust, weed-free straw (e.g., rice straw), nut shells, or other regionally-appropriate mulch materials that contain no viable weed seeds.

Transplant installation should be timed to avoid prolonged periods of hot, dry, or windy weather. Regardless of when planting occurs, however, the transplants should be irrigated thoroughly immediately after planting. Holes for plants can be dug and pre-irrigated prior to planting as well. Follow-up irrigation is dependent upon weather and specific site conditions, but generally even native and drought-tolerant plants should be irrigated with at least 1″ of water per week (except during natural rain events), for the first two years after establishment. Long, deep watering, via drip irrigation, is best to encourage deep root system development. Irrigate at the base of plants, and avoid overhead irrigation, which encourages weed growth. Once plants are established, irrigation should be removed or greatly decreased.

Below-ground wire cages are recommended if rodent damage is likely. Similarly, plant guards may be needed to protect plants from above ground browsing or antler damage by deer.

Monarch butterfly, honey bee, and leafcutter bee all nectaring on a milkweed flower. Milkweed are highly attractive to many pollinators. (Photograph by John Anderson, Hedgerow Farms, Inc.)

## Ongoing Management

Newly planted areas should be clearly marked to protect them from herbicides or other disturbances. Signs can be particularly useful during the establishment phase, when the planting may not yet be easily recognizable as habitat.

Following planting, weeds should be prevented from going to seed in or adjacent to the project area during the first two years. Common weed management strategies include careful spot-spraying with herbicides, use of grass-selective herbicides to control weedy grasses, or use of mowing or string-trimming. When planted with perennial seed mixes, sites can be mowed occasionally (ideally as high as mower settings allow) during the first year after planting to prevent annual and biennial weeds from flowering and producing seed. Perennial wildflowers are slow to establish from seed, and are usually not harmed by incidental mowing in the first year after planting.

Established habitat also needs some maintenance over time. Possible management tools/ techniques to maintain wildflower plantings include mowing or burning. If mowing is used, be sure all equipment is clean and free of weed seed. Do not mow or burn during critical wildlife nesting seasons (consult your state wildlife biologist for specific guidance). After establishment, no more than 30% of the habitat area should be mowed or burned in any one year to ensure sufficient undisturbed refuge areas for pollinators and other wildlife.

Ongoing management of woody plant habitat includes removing tree guards or other materials that could impede plant growth after establishment. In most cases, irrigation can be removed from transplants by the end of the second year after planting. Ongoing herbicide use (spot-treatment) or occasional hand- weeding may be necessary to control noxious weeds.

# Choosing Garden Plants

Many plants native to North America, but not necessarily native to your area, are wonderful pollinator plants and well-suited to gardens. Similarly, many other flower garden plants that originate from Europe and elsewhere provide abundant nectar and pollen. English lavender and most culinary herbs are good examples. As a general rule of thumb, heirloom varieties of perennials and herbs are the best sources of nectar or pollen. Newer hybrid flower varieties often have been bred for color or size and, in the process, may inadvertently have lost some of their ability to produce nectar and pollen. Varieties with double petals are often indicative of plants that have been extensively bred and may lack pollen and/ or nectar resources. See Appendix B for garden plant recommendations.

Long-horned bee foraging on a cosmos flower. Cosmos is a great plant to include in a farm garden or for the sale of cut flowers. These flowers hum with native bees in summer months and are easy to grow. (Photograph by Mace Vaughan, The Xerces Society.)

# Planting Forage Cover Crops

Flowering cover crops are a simple and effective way to quickly increase the amount of pollen and nectar available on the farm. The ground beneath the rows of orchards, blueberries, cane crops, and vineyards, as well as the lawns around buildings, roadside strips, and fallowed fields can easily be sown with a ground cover that provides nectar and pollen for supporting native bees. Cover crops can also provide several other benefits, such as improving erosion control and soil permeability, fixing nitrogen, discouraging weeds, and harboring beneficial insects. Plant selection and the timing of crop termination are the two keys to maximizing the impact of cover crops for bees.

## Plant Selection

Nectar-rich broadleaf cover crops should be prioritized when selecting cover crop species for bees. For example, various clovers, vetches, brassicas, and lacy phacelia are common cool-season cover crops that are highly attractive to various bees. Depending on the location, a variety of warm-season cover crop species such as buckwheat, sunn hemp, cowpea, and sunflower are also available. When used in combination with high-quality, permanent native plant habitat on the farm, overlapping cool-season and warm-season cover crop rotations can sustain robust bee populations throughout the year.

In recent years there has been a trend toward diverse, multi-species, cover crop seed mixes ('cocktails'). While this practice is still in its infancy, the benefit to bees is likely significantly higher than that of single species cover crops. In particular, the inclusion of many different flowering broadleaves in a cover crop seed mix will provide an extended period of flowering, and will provide a variety of flower shapes and types to attract and sustain a diversity of bee species. Table 6.1 provides an example of a diverse, multi-species, cool-season cover crop seed mix.

While grasses are not typically attractive to bees, grass cover crops such as rye and oats provide other benefits (including benefits to soil health), and are easily integrated into diverse, multi-species seed mixes.

Finally, to reduce the possibility of increasing crop pests, we recommend caution when considering the use of cover crop plants that are closely related to cash crops. For example, if brassicas such as broccoli or cabbage are your primary cash crops, it may be advisable to minimize the use of brassica cover crops such as turnip, radish, or mustard, all of which may host the same pests and diseases.

Despite this caution, we strongly suspect that multi-species cover crops will generally reduce pests by increasing populations of the beneficial insects that prey upon them. Additional research is needed to compare the pest management benefits of multi-species versus single-species cover crops, but the overwhelming general trend revealed by most research is toward reduced pest pressure in highly diversified crop systems.

**Table 6.1: Sample Cool Season Cover Crop "Cocktail"**

| SPECIES | % OF MIX | LBS/ AC. |
|---|---|---|
| Phacelia | 8% | 0.5 |
| Crimson clover | 8% | 0.75 |
| Radish (daikon) | 8% | 1.75 |
| Hairy vetch | 8% | 5.5 |
| Field pea | 8% | 40 |
| Turnip | 8% | 0.5 |
| Fava bean | 2% | 70 |
| Rye | 25% | 15 |
| Oats | 25% | 17 |
| **TOTAL** | **100%** | **151** |

Formulated for one acre at 25 seeds per square foot

## Cover Crop Termination and Residue Management

Many farmers are increasingly adopting "cover crop cocktails." This cool-season cover crop in North Dakota includes vetch, radish, oats, turnip, phacelia, and several other species. (Photograph by Eric Lee-Mäder, The Xerces Society.)

While necessary to prepare for cash crop rotation, terminating a cover crop can be difficult for pollinators, especially if the cover crop is still flowering at time of termination. The risks to bees from cover crop termination include direct mortality (such as being crushed by cultivation or roller-crimping equipment), and indirect harm such as the rapid loss of available food sources. Even when adult bees are not active and/ or present in a cover crop, egg-filled nests or hibernating adults may still be present in the crop residue or in the soil.

To reduce some of the impact of cover crop termination, we recommend the following:

- Where possible, wait until most of the cover crop is past peak bloom (but before cover crop seeds are mature) to terminate.
- Terminate with as little physical disturbance as possible (for example, roller-crimping may be less disruptive to bee nests in the soil than cultivation).
- Maintain permanent conservation areas on the farm to sustain bees in the absence of the cover crop.
- Leave as much cover crop residue as possible to protect nests and any dormant adult bees (such as bumble bee queens).
- Minimize insecticide use in cash crops where cover crops were previously planted to avoid harming bees that may still be nesting within the cover crop residue. At a minimum you should follow an IPM plan that includes risk mitigation strategies designed to protect pollinators.

California bumble bee visiting fava bean blooms. An excellent cool-weather cover crop, fava bean can provide forage for bees in early spring or late fall. (Photograph by Rich Hatfield, The Xerces Society.)


A bumble bee nectars on a phacelia bloom. Phacelia is a promising plant for pollinator-friendly cover cropping. (Photograph by Katharina Ullmann, The Xerces Society.)

### Limitations of Cover Crops

Although cover crops can provide a significant pollen and nectar resource for bees, it should be recognized that they do have limitations. For example, because most cover crops are temporary, they may present a "feast or famine" situation for bees with an abundance of food, followed by a food shortage. Under such circumstances wild bees may have limited reproductive success.

Additionally, because most cover crop plants are non-native, their attractiveness to native bees may be highly variable. In general, most bees attracted to cover crops tend to be species that are already relatively common. Less-common native bees often require plant communities comprised primarily of native plant species. Therefore, to maximize pollinator diversity and abundance, cover crops should be used in combination with high-quality, pesticide-free native plant habitat that is maintained in other areas on the farm.

### Balancing Pollinators with USDA Cover Crop Rules

Federal crop insurance programs may have region-specific requirements for cover crop termination. These rules typically occur in the drier western states, and are intended to balance the soil–water needs of cash crops following in rotation with cover crops. They typically require the termination of cover crops in advance of cash crop planting (sometimes even before the cover crop has finished flowering).

This scenario further demonstrates the need to supplement pollinator-friendly cover crops with other conservation areas such as hedgerows, permanent wildflower meadows, and buffers. To further reduce the impact of cover crop loss, it may be possible to leave small sections of it in place (such as a single outer row), rather than terminating the entire field for cash crop rotation. Even such small sections can help sustain pollinators in the absence of other forage sources.

For current guidance on cover cropping and crop insurance rules, consult your local NRCS office or crop insurance agent. See Appendix D for sources of additional information on cover cropping.

## Consider Bees When Rotating Crops

It is likely that a particular crop grown consistently in one area will develop a population of wild native bees that are regular visitors. If rotating crops, consider the possibility of moving a crop no more than a few hundred yards away. For example, pumpkin and winter squash fields may build up significant numbers of squash bees in and around the fields. Maintaining squash plantings with the landscape may help sustain these populations of specialist pollinators.

# Case Study: North Carolina Farm Sets the Stage for Pollinators with Crop Diversity and Solarization

It's clear to see that when Rob and Cheri Bowers set out to create their farm, they wanted to blur the lines between agriculture and nature. The result of that vision is Whitted Bowers Farm located in Cedar Grove, North Carolina, a diverse 52-acre farm that uses organic, biodynamic, and permaculture principles as a foundation for even more ambitious goals. High on that list of goals is an effort to foster pollinator and beneficial insect habitat across the entire farm landscape.

Beginning with an amazing diversity of fruit and heirloom vegetable crops, including strawberries, blueberries, blackberries, raspberries, watermelon, and tomatoes, the fields of Whitted Bowers provide a continuous supply of bee-attractive crops throughout the growing season.

These bee-attractive crops are supplemented with the extensive use of flowering cover crops, such as crimson clover, which further extend the availability of pollen and nectar throughout the year. And, going one step further, the Bowers have worked to establish a growing network of native wildflower field borders on the farm.

To establish more native wildflower field borders, the Bowers are now testing the use of soil solarization to eliminate weedy plant competition prior to planting. The solarization process uses a large sheet of UV-stabilized, high tunnel greenhouse plastic (with the edges buried) to heat the ground, killing weeds and weed seeds below. (In initial nationwide trials conducted by Xerces, solarization has proven even more effective than chemical herbicides in clearing an area for replanting with native wildflowers.)

Finally, while the diversity of crops, cover crops, and wildflowers obviously support bees, these resources also have made Whitted Bowers Farm rich in other beneficial insects, such as syrphid flies, which prey upon pests. The resulting combination is a landscape rich in beneficial insect food resources and a safe haven from insecticides—exactly the balance of nature and agriculture the Bowers had in mind.

Solarization in progress at Whitted Bowers Farm. It is important to bury the edges of your UV-stabilized high tunnel greenhouse plastic when using solarization to control weeds. (Photograph by Nancy Adamson, The Xerces Society.)

# 7

# Protecting and Creating Bee Nest Sites

Although bees are able to nest in one type of landscape and forage in another, it is important that those two key elements of bee habitat are not separated by too great a distance. Whenever possible, nesting sites should be close to crops and areas of foraging habitat. Female bees typically travel less than a half-mile from their nests to find nectar and pollen, and small native species may only fly a few hundred feet. Nest sites that are closer to agricultural fields will provide the greatest pollination benefit.

Ground-nesting bees, like this solitary polyester bee may nest in large aggregations when soil conditions are right: usually gently sloping, well-drained, and facing towards the south. (Photograph by Steve Javorek.)

## Nesting Sites for Ground-Nesting Bees

Most bees nest in the ground. Your farm likely is already home to a number of ground-nesting bees. Protect existing nest sites whenever possible. Look for potential nest locations in areas with well-drained soil and patches of bare or partially-bare ground with plenty of sun exposure. Keep in mind that different ground conditions—from vertical banks to virtually flat ground—draw different bee species. Tunnel entrances usually resemble flat ant mounds, with small piles of excavated earth surrounding a perfectly round entrance hole. Entrance holes might be very small in diameter to more sizable (⅛″–¼″), and may be solitary or grouped together with other entrances. Flags can be used to mark nest sites so when nests are capped and no longer visible from the surface their location is still known and ground-level disturbance to that site can be avoided.

This nest has been excavated to show the entrance tunnel and a couple of brood cells. When the conditions are right, a cubic foot of soil can contain hundreds of nest cells, each cell containing a bee that will emerge the following year. (Photograph by Dennis Briggs.)

## Maximize Undisturbed Ground

When trying to conserve ground-nesting native bees, we recommend starting with the simplest approach: maximize areas around a farm where the ground is undisturbed. Avoid tillage in areas that may be occupied by nesting bees. Turning over the soil destroys all of the ground nests that are present at that depth and hinders the emergence of bees nesting deeper in the ground. Buried under the ground at a strong nest site may be thousands of bees that will emerge the next year. For this reason, it is best not to dig deeply into the soil unless absolutely necessary. Ground-nesting squash bees, which can naturally occur in large enough numbers to make honey bees redundant, are three times as abundant on no-tillage farms as on tilled farms.

Flood irrigation, high-intensity grazing, and off-road vehicle use can also cause disturbance to ground nests. Fumigants used to control soil crop pathogens, along with soil drenches of systemic pesticides, can also be harmful to ground-nesting bees. Avoid covering large areas with landscape fabric or plastic mulch, which can deter bees from accessing the soil.

## Artificial Nest Sites for Ground-Nesting Bees

Setting aside undisturbed habitat for ground-nesting bees is likely the best step you can take to support nest sites for ground-nesting bees. Although the nesting habitat requirements of one ground-nesting bee species, the alkali bee, are so well understood that artificial nesting sites are created commercially to provide reliable crop pollination for alfalfa in Idaho and eastern Washington, the *precise* conditions needed by most other ground-nesting bee species are not well known. As such, attempts to recreate nest conditions for other ground-nesting species have not been consistently successful. The following suggestions for creating new potential nest sites for ground-nesting bees might be most useful for educators or researchers interested in experimentation to improve these approaches and develop region-specific strategies for maximizing ground-nesting opportunities.

Semi-bare ground on a gentle slope, such as under this small orchard, can support thousands of nesting bees. Each small pile of soil is a mining bee's nest entrance. (Photograph by Matthew Shepherd, The Xerces Society.)

Seventy percent of North America's native bee species are ground-nesters. The entrances to their burrows may resemble ant hills. (Photograph by Eric Lee-Mäder, The Xerces Society.)

Nest sites for ground-nesting bees can be created through processes that expose bare ground. Consider clearing some of the vegetation from a gently sloping or flat area that is not under cultivation or at risk of erosion. The goal is to clear away the thatch and provide the bees with access to the soil below, while still leaving clumps of grass or other low-growing plants. The site should be well-drained, in an open, sunny place, and, where possible, on a south-facing slope. Different ground conditions—from vertical banks to virtually flat ground—draw different bee species.

Another approach is to create a pile of soil, perhaps with soil excavated from silt traps or drainage ditches, stabilized with bunch grasses and wildflowers. Different species of bees prefer different soil conditions, and research shows that many ground-nesting bees prefer sandy or sandy-loam soils (for example, a soil mix of at least 35% sand). The easiest approach is to pile up soil from the farm, but then to also consider mixing in some sand.

Despite these efforts, colonization of these sites will depend upon the bees that are already in the area and the suitability of other nearby sites. Artificial nest construction for ground-nesting bees has produced variable results.

### Maintenance of Nests for Ground-Nesting Bees

In general, it is important that ground nest sites receive direct sunlight and that bare soil—even very small patches—is accessible among the plants. This might mean trimming back bushes or trees from time to time and keeping thatch, weeds, grass, or moss from becoming too dense and blocking bee access to the soil below. Other management tools might include spotty herbicide treatments, fire, and haying. Clippings or dead plant material should be mostly removed from the site. Ideally, site management should occur in the fall when adult bees are not present.

## Nests for Wood- or Tunnel-Nesting Bees

Your farm may already have existing nesting habitat for wood- or tunnel-nesting bees. Many bees, such as leafcutters and masons, naturally nest in beetle tunnels and similar holes in snags (standing dead trees). If snags do not pose a hazard, keeping them will provide habitat for bees as well as habitat for birds and other wildlife. Brush piles likely harbor wood- or tunnel-nesting bees. Some bees will nest in hollow plant stems, or excavate older pithy stems. Maintain existing plants or grow additional plants that provide nesting habitat for bees (see left).

In addition to nesting holes themselves, different bee species need different materials to construct brood cells and seal their nests. A few wood-nesting bees secrete a cellophane-like substance to divide brood cells, but most use gathered materials, such as pieces of leaf or petal, mud, fine pebbles, or tree resins. These materials may already be present, but providing a diversity of native plants and some mud puddles may be beneficial.

**Plants with Stems That Bees Utilize as Tunnel Nests**

- Box elder (*Acer negundo*)
- Agave (*Agave* spp.)
- Sunflower (*Helianthus* spp.)
- Sumac (*Rhus* spp.)
- Wildrose (*Rosa* spp.)
- Raspberry, blackberry (*Rubus* spp.)
- Elderberry (*Sambucus* spp.)
- Cup plant (*Silphium perfoliatum*)
- Snowberry (*Symphoricarpos* spp.)
- Ironweed (*Vernonia* spp.)
- Yucca (*Yucca* spp.)

## Artificial Nests for Tunnel-Nesting Bees

Many species of tunnel-nesting bees will nest readily in artificial nests, including several species that can be managed for commercial crop pollination, the blue orchard bee (*Osmia lignaria*) and alfalfa leafcutter bees (*Megachile rotundata*).

## Wooden Blocks

A standard, commercially made bee nest is a wooden block with many holes drilled in it. The holes are usually 5⁄16″ in diameter, the size preferred by blue orchard bees. These blocks are very simple to make. A range of hole sizes will further support a variety of tunnel-nesting bees, encouraging the delivery of pollination services over a longer period of time, beyond the flight season of blue orchard bees.

Preservative-free lumber works well: a 4″x4″ for blocks with holes narrower than ¼″, or a 4″x6″ for blocks with holes wider than ¼″. A rough block of wood, firewood, or a log also can be used, as long as it is deep enough. The height of the block is less important, although most are constructed at least 8″.

In one side, drill a series of nest holes. Each hole should be between 3⁄32″ and ⅜″ in diameter. Holes ¼″or less in diameter should be between 3″ and 5″ deep. Holes larger than ¼″ in diameter should be 5″ to 6″ deep. This is because the female bee, which controls the gender of her offspring, always finishes the nest with a few male brood cells. Deeper holes ensure more space for female brood cells. Female bees provide a greater benefit to crops, since it is the female that visits flowers to collect pollen and nectar to provision her offspring.

If the goal of a restoration project is to try to maximize the production of native bees from nest blocks, then it is worthwhile to create multiple blocks, with each block drilled with a single tunnel diameter. This will make block maintenance easier (see section in this chapter: Maintaining Nests for Wood-Nesting Bees). If, however, the goal is to improve the overall habitat for native bees with little follow up management, then we recommend drilling a variety of hole sizes into a single block of wood and putting it in the field.

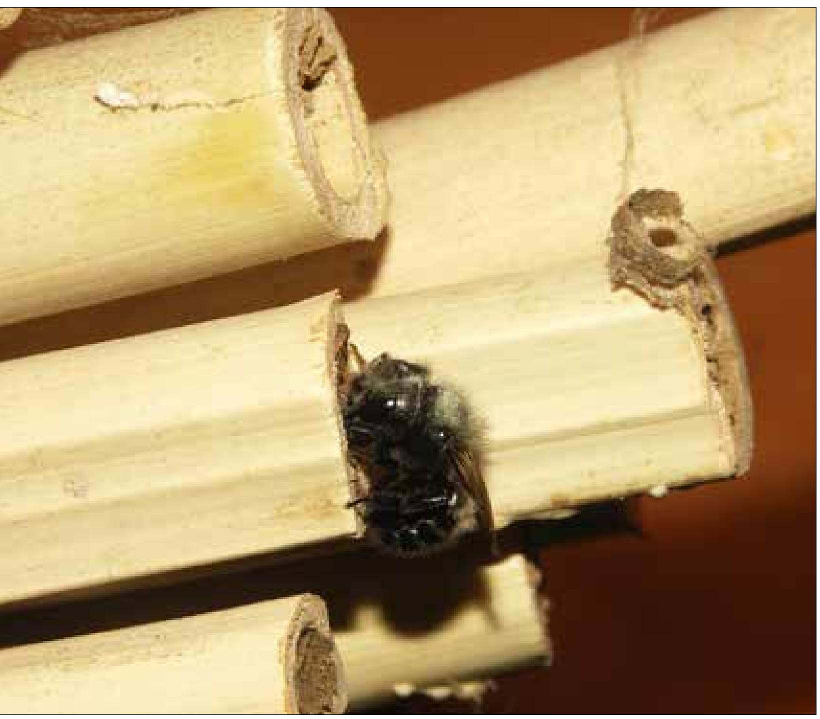
Some species of native bees excavate nests in the pithy stems of plants. Here, a small carpenter bee is nesting in a blackberry cane. (Photograph by Nancy Adamson, The Xerces Society.)

Close-up of a nest block drilled with a variety of hole sizes for tunnel-nesting solitary bees. This is part of a pollinator restoration site in California. (Photograph by Katharina Ullmann, The Xerces Society.)

The holes in a nest block should be about ¾″ from center to center, and no closer than that to the edges. Attach a backing board if holes are drilled all the way through the block, because bees will not use a hole that is open at both ends. Smaller diameter drill bits may not be able to achieve the 3″ minimum recommended depth; in this case, holes should simply be drilled as deeply as possible. Bees that use smaller diameter holes will often nest successfully in holes that are not as deep.

Because bees may avoid a rough interior, very sharp drill bits should be used, the drill should be set at the highest speed possible, and, when possible, holes should be bored across the grain. Paper straws also can be used to line the holes, although it may be hard to find straws that fit all diameters. Paint the outer tips of the straws black or red to help attract bees.

An overhanging roof can be attached to the nest to provide additional shelter from rain or midday sun. Landmarks can be incorporated on the face of the block to help the bees visually orient themselves. These landmarks can be simple splotches of color painted on the face of the block. Neither of these amendments are necessary, but they can help protect the block and provide additional cues for the bees.



There are many ways to provide habitat for tunnel-nesting bees (e.g., leafcutters and mason bees). Nest sites can include a bundle of hollow stems (above) or a stack of grooved planks (next page). (Photograph by Mace Vaughan, The Xerces Society.)

## Other Tunnel Nests in Wood

For a more rustic or natural alternative to a bee block, holes can be drilled into a log or piece of scrap lumber, then erected like a fence post to simulate a beetle-tunneled snag. Standing dead wood can also be drilled with holes for tunnel-nesting bees.

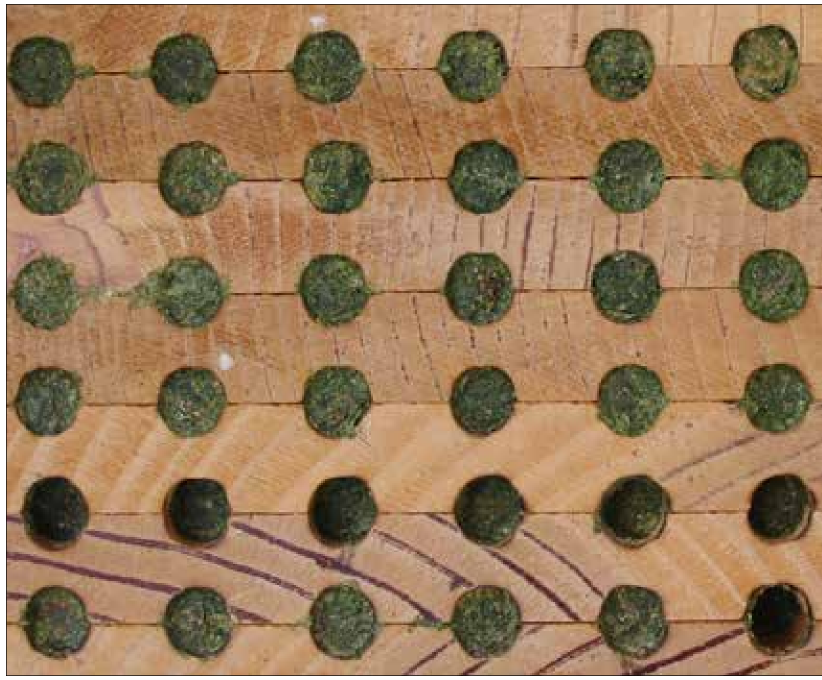
## Bundles of Stems or Straws

Another option is to make nests from bundles of hollow stems or straws. Bamboo, teasel, and common reed are good choices because their hollow stems are naturally blocked at the stem nodes (usually indicated by a ridge). Cut each stem below the nodes to create a handful of tubes, each with only one open end. Strap the hollow stems 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. Another variation is to tightly pack stems or paper tubes into a tin can, paper milk carton, or short section of PVC pipe.

A cross-section of bamboo stem being used as nesting substrate illustrates the distribution of brood cells in a tunnel nest. (Photograph by G. Neuenswander.)

## Location and Orientation of Nests

Nest blocks, or bundles of tubes or stems, should be mounted in a location that receives morning sun, but has some protection from the extreme midday summer heat. Generally, the nest entrances should face southeast, so that the bees can be warmed as quickly as possible in the morning. Nests also should be erected at least 4′ above the ground to raise them above cool moist air that may pool at night, and they should be fastened securely so that they do not move in the wind.



When her nest is completed, the bee will seal it before she leaves. The seal is generally made with the same materials used for the nest, such as leaf pieces (shown here), mud, or tree resin. (Photograph by Matthew Shepherd, The Xerces Society.)

## Maintaining Nests for Wood-Nesting Bees

Whether nesting sites are wooden blocks, twig bundles, or other materials, the most significant maintenance issue is whether and when to clean out the holes. In general, cleaning will help to reduce parasites, fungi, and diseases that might affect the developing bees in their brood cells.

The advantage of using paper straws to line the holes is that the nest block will be easy to clean. At the end of summer, pull out the straws containing brood cells and dormant pupae and carefully store them in a cool place (as low as 36° to 39° F) over the winter, perhaps in an unheated but frost-free shed, garage, or even in the refrigerator. The straws should be in a ventilated container to prevent them from molding.

Be gentle with the occupied straws and keep them horizontal or with the entrances facing up so that the larvae stay with the food stored at the back of each cell. The empty blocks can then be washed with a mild bleach solution, dried, and stored for the winter.

In the spring, do not put the occupied straws back into the blocks; instead, insert new straws to create clean nesting sites and return the blocks to their previous locations. Meanwhile, take the occupied straws from storage, bundle them, and place them in a box with a single exit hole, 1″ in diameter. Place the box beneath the new straws. When the bees emerge, they will leave the box through the exit hole and most will create brood cells in the new straws. After the bees emerge, throw away the abandoned straws so that they do not get reused.

Cleaning wooden blocks with holes that have not been lined with straws is difficult because many of the holes may remain occupied throughout the year. To limit the build-up of parasites, destroy the blocks or re-drill the holes in the nesting blocks every three years. To encourage the bees to emerge and not return to the same holes, place the blocks in a box that has a single exit hole, 1″ in diameter. When the bees emerge they will leave the box through this exit hole and not return to the nests. When the plugs sealing the nests have been broken, the bees will have emerged. Growers can clean the blocks with a mild bleach solution and re-drill the holes or remove and destroy the blocks. For additional information on ways to rid nest blocks of parasites, see the guide *Managing Alternative Pollinators* (Appendix D).

## Bumble Bee Nests

Two general methods are used to increase bumble bee nest sites. The first is to protect or create habitat in which bumble bees nest. The second is to construct artificial nest boxes and place them in suitable locations around the farm. Unfortunately, even in the best situations, no more than 30% of artificial bumble bee boxes are occupied. Building a bumble bee nest box takes time and energy and isn't likely to be practical for most growers. Because of this constraint, this section will focus on how to provide or protect habitat where bumble bees nest. More information on designs for constructing nest boxes for bumble bees is included in the book *Attracting Native Pollinators*.

Several studies conducted around farms and other landscapes demonstrate that bumble bees are found more often in the grassy interface between open fields and hedgerows or woods. This is likely the case because of the greater number of available nest sites in these habitats. The cover provided by the plants in these transitional areas creates conditions favored by nesting rodents, which results in potential nest sites for bumble bees, either below ground or among the tall grasses. Areas of habitat suitable for bumble bees should include a mix of native bunch grasses abutting shrubs or trees.

Bumble bees usually build jumbled nests of honey pots and brood cells in cavities in the ground or under clumps of grass. (Photograph by Elaine Evans.)

The grass should be planted in a strip at least 5′ wide and not mowed. Ideally, the grass will grow tall and fall over in clumps under which rodents will build nests or burrow into the ground. A row of shrubs and forbs can be planted behind this swath of grass, which will provide cover and forage for both bees and rodents. A farm road or well-mown strip of grass will act as a barrier between the natural habitat and crop and discourage rodents from entering agricultural fields.

Another option for providing bumble bee nesting habitat might be to simply let a small part of the farm grow wild for a year or two without cutting the plants. At one site near Davis, California, dozens of queen bumble bees were collected among abandoned army barracks. This site was probably pesticide-free and had large areas of lawn and hedge that grew unencumbered for several years, creating optimal conditions for bumble bees.

Protect bumble bee nesting habitat by avoiding or limiting near-surface or subsurface disturbance; mowing, fire, tillage, or grazing can damage bumble bee colonies or harm overwintering queens. Do not disturb the entire site at one time, and only disturb one third of the site per year. See the Xerces Society publication *Conserving Bumble Bees* for more specific guidelines (Appendix D).

# Pollination Insurance for Massachusetts Cranberries

By Linda Rinta, Plymouth County Conservation District

Knowing what we do about Colony Collapse Disorder and high winter honey bee losses, the vagaries of weather, the question of climate change, and the increase in competition for beekeepers to provide pollination services, would you buy a little pollination insurance if you could?

Indeed, you can. If we open some of our land to pollinator habitat and modify our crop protection strategies a bit, then we can restore some of the baseline pollination that used to exist naturally around cranberry bogs in Massachusetts. Habitat alone in cranberry bogs may not necessarily provide all the pollination needed to grow this spectacular crop. But it's cheap insurance and a bridge toward widening the pollination "window of opportunity."

## So Let's Talk Bumble Bees

For insurance purposes among cranberry growers, bumble bees are the key. While other wild bees are also important, bumble bees are the workhorse group for cranberry pollination. Bumble bees evolved with cranberries and actually like cranberry flowers! They are able to "buzz pollinate" these flowers by vibrating the anther to release pollen, which means that—unlike honey bees—they are able to gather <u>both</u> pollen and nectar from cranberry flowers. As a result, cranberry flowers are much more attractive to bumble bees than they are to honey bees.

The formula for re-establishing or enhancing natural populations of bumble bees where they have almost vanished includes restoring nesting areas, supplying floral diversity throughout the growing season, protecting hibernation areas for queens, and adjusting our pest management practices to accommodate bumble bees in an entirely different way than honey bees.

## Nesting Areas

Forget about those fancy bumble bee boxes. Bees follow mice. They like rodent holes, brush piles, and stumps. The important thing is: don't mow it, drive over it, dig it up, or drag it off.

## Restore Wildflowers

Bumble bees store very little food in their nests, so they need to forage in pesticide-free habitat nearly every day. Even a week without pollen- and nectar-rich flowers within their foraging range can be devastating to a bumble bee colony. The few wildflowers that our farms provide are ephemeral at best: a little bit here and there, now they bloom, now they don't, and then we mow. Moreover, in Massachusetts, our cranberry bogs are typically surrounded by a curtain of privacy trees that provide little value for pollinators.

When working with growers in our community, I recommend that they take a look at their bog edges and non-crop areas every week throughout the season to see where there are missing wildflower resources for bees. Where wildflowers are completely absent, the big opportunity is to create new meadow strips of native wildflowers. As an example of this strategy, after two years of work with the Xerces Society, the Cape Cod Cranberry Growers Association, and the University of Massachusetts Cranberry Station, we jointly identified a group of plants that are fantastic for bumble bees and which cranberry growers didn't immediately perceive as weeds! The list was short, but substantial: wild lupine, wild blue indigo, golden Alexanders, smooth penstemon, blazing star, butterfly milkweed, lavender hyssop, purple coneflower, wild bergamot, and Virginia mountain mint, with a little annual partridge pea thrown in for bloom the first year.

In addition to new upland meadow plantings, we also have learned to consider the brushy edges around the reservoirs that feed into bog systems, and have looked for ways to improve these areas as pollinator habitat. For example, in late summer in Massachusetts, these areas host a lot of natural floral abundance, such as Joe Pye weed, buttonbush, and sweet-pepper bush. While these summer plants are fantastic for bees, we've been asking ourselves if there isn't also an opportunity to encourage more spring blooming plants in these areas? For example, while most growers hate pussy willow, we've been asking ourselves whether we can learn to tolerate it in places where it won't spread? Similarly, we are having conversations about pushing back our heavy forest edges and adding smaller spring-blooming trees and shrubs such, as redbud or beach plum.

## Tolerate a Little Goldenrod on the Side

The last hatch of bumble bees at the end of the season is especially important because it includes the new queens for the next year. The number of queens is thought to be determined by the abundance of fall forage resources, which in the New England means goldenrod and aster—beautiful plants that are unfortunately often viewed as weeds. Goldenrod and asters make bumble bees queens fat, and fat queens are those that will most likely survive winter dormancy to start new colonies the following year.

## Pest Management and Bumble Bees

Bumble bees make pest management a challenge, because, unlike honey bees, they sometimes sleep outdoors. Similarly, they often begin work at the crack of dawn and can be active until fairly late in the evening. Because of this constant presence in the bogs, we have learned that when a pesticide must be applied during bloom, it is critical to seek out products that are the least-toxic option available. Another trick we've learned is to run bog sprinklers late in the day to help drive off some of the bees, and then conduct the spraying over night. Another critical recommendation we make with our growers is to mow any blooming weeds next to areas that will be sprayed. And, of course, don't spray habitat areas at all.

## The Best Insurance Is a Group Policy

As you think about your farm, think about interconnected streams and islands of pollinator habitat that are protected from pesticide drift. If you are successful, bumble bees will prosper, local honey bees stand a better chance of surviving the winter or building up prior to a crop bloom, and other pollinators and beneficial insects will increase. Together, these partners in pollination will ensure abundant harvests.

The final critical step, however, is to engage the other farmers in your community. Recognize that when you link your pollinator habitat to that of your neighbors, you create an entire farm community that ensures abundant crop yields for itself, that is resilient to changes in climate or honey bee availability, and that is a beautiful place to live. Who would have thought that a simple focus on bumble bees could offer so much?

## The Innovative Cranberry Grower: Standish Bogs

All the components of good bumble bee habitat have been put into play at Standish Bogs, near Plymouth, Massachusetts. Chet Halunen has worked closely with Linda Rinta and the Xerces Society to create and manage beautiful bumble bee meadows overlooking his bogs (upper right).

These meadows are full of lupine, mountain mint, and dotted mint. They hum with bumble bees and honey bees, as well as other beneficial insects that are attacking pests on the bog. As time goes on, the goldenrod (lower right) is slowly moving in—up and away from the bogs—where it provides late season bee forage, and where Chet is happy to see it bloom.

A mix of native wildflowers, including wild lupine, dotted mint, and marsh blazing star provides continuous forage for bumble bees from early spring through fall. (Photograph by Linda Rinta, Plymouth County Conservation District.)

Goldenrod is an excellent late-season source of forage for new bumble been queens in the fall. Below, goldenrod at Standish Bogs attracts a variety of bees and wasps. (Photograph by Linda Rinta, Plymouth County Conservation District.)

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# Insecticides and Pollinators

Bumble bees are important pollinators of blueberry. They are not the only native visitor, though, more than 60 species of native bees have been documented to visit these flowers. (Photographs by Rufus Isaacs, Michigan State University [above], and Nancy Adamson, The Xerces Society [below].)

While pesticides are a tool used to control pests, they have a negative impact on native bee and beneficial insect populations. Perhaps the first time the impact of insecticides on crop-pollinating native bees was studied dates back to the early 1970s. Blueberry farmers in New Brunswick, Canada, experienced a sudden crash in their harvests because of the disappearance of native bumble bees, mason bees, and mining bees that pollinated their crops. They later learned that the lack of bees was due to aerial spraying with fenitrothion on adjacent woodlands to kill spruce budworm. The spraying was stopped, but it took several years for bee populations to recover and fruit harvests to return to pre-spraying levels.

Today, research by Agriculture and Agri-Food Canada continues to look at the impact of insecticides to native bees and blueberry production in the Canadian Maritimes. At least 67 species of native bees play a role in blueberry pollination in Nova Scotia. After insecticides are applied to these fields, native bee populations drop by an average of 50%. This research illustrates the value of native bees to these crops and the long-term impact of insecticides—even those sprayed outside the boundary of a farm—on a community of native pollinators.

Since the 1970s there have been many documented cases of insecticide poisoning of bees. This problem continues to affect native bees and honey bees. In Washington State alone, over 179 honey bee poisonings were investigated between 1992 and 2006. This number may drastically underestimate the number of poisonings of native bees, which are not afforded the same protection as managed hives of honey bees.

# Lethal and Sublethal Effects of Insecticides

Bees can be killed outright by exposure to insecticides in treated fields or adjacent areas contaminated by drift or overspray. Many native bees, which are smaller in size than honey bees and are exposed to a relatively higher dose relative to their body size, may be killed by lower concentrations of insecticides than are honey bees.

Bee kills are not the only impact of insecticides. Bees exposed to sublethal doses of insecticides in the field may have trouble navigating back to the nest after foraging, or they may simply be unable to fly. Other symptoms include agitated behavior, jerky or wobbly movements, and paralysis. These changes in behavior impede foraging and nest building, leading to the premature death of the bee or her offspring. Sublethal doses also can reduce colony growth and queen production of bumble bees, egg-laying by female solitary bees, or inhibit the growth of larval bees.

**Looking for More Information on IPM and Protecting Pollinators from Pesticides?**

For detailed guidance on how to incorporate pollinator protection into farm IPM plans, download a copy of the USDA–NRCS Technical Note *Preventing or Mitigating Potential Negative Impacts of Pesticides on Pollinators Using Integrated Pest Management and Other Conservation Practices*. (Available at: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=34828.wba)

## Bee Exposure to Insecticides

Bees are exposed to insecticides through a number of pathways present in fields as well as adjacent habitat nearby.

- Direct contact with insecticide spray can occur when bees are present within a field, foraging or nesting, at the time of insecticide application. Bees might also be foraging on bee-visited crops or on blooming plants in field margins or orchard understories.
- When bees visit fields, or contaminated adjacent field margins, after an insecticide application, they contact residues still present on flowers or leaves. If an insecticide has a long period of residual activity, contact with residues can occur days after the application.
- Bees come into contact with insecticidal dust released from planters of insecticide-treated crop seeds (e.g., clothianidin-treated corn seed) while flying, or when dust settles on flowers adjacent to fields.
- Bees collect and ingest nectar and pollen contaminated with residues from systemic insecticides applied as seed coatings, foliar sprays, oil drenches, or trunk injections. Some systemic insecticides can remain persistent in plant tissues and in soil beyond a single growing season.
- Wettable powders, dusts, and microencapsulated formulations adhere to the hairs on the bodies of bees and may be carried back to nests along with pollen.
- Some bees gather water for use in their nest excavation process. Their water sources can include surface water contaminated by field run-off, drift, or insecticidal dust, and leaky chemigation systems.
- Applications of insecticides may contaminate potential nesting sites for ground-nesting bees, as well as tunnel-nesting bees. Bees that use leaves or other plant materials in their nest construction (e.g., leafcutter bees) may be exposed when those materials have been contaminated.

# Reducing the Need for Insecticides

Given the damage insecticides inflict upon pollinators, use of these chemicals should be eliminated or reduced whenever possible. However, if insecticides must be used, look for application methods that reduce both the amount of material applied and the negative impacts on beneficial insects. For example, instead of applying insecticides on a calendar schedule, growers can learn how to field scout for pest problems or how to track degree-days to know when insecticide applications will be most effective at the smallest dose. Integrated Pest Management (IPM) is a decision-making framework for using least hazardous pest management options when there is a demonstrated need, both within conventional and organic farming systems. IPM employs a four-phase strategy:

**Step 1.** Prevent conditions that favor pests. This step includes practicing good sanitation and removing the pests's alternative plant hosts. This step also incorporates strategies that interrupt pest cycles or keep their populations low through nontoxic means, such as managing habitat for beneficial insects, using mating-disruption pheromones, or practicing thoughtful crop rotation.

**Step 2.** Establish an economic threshold. This is defined as a pest population density or level of crop damage at which action should be taken to avoid an economic loss.

**Step 3.** Monitor pest populations or pest damage.

**Step 4.** Take action to control pests only when populations or damage exceed the economic threshold; the cost of pest control should be less than the loss of income caused by the pests. Use pest control in the most targeted way possible.

IPM planning can encompass pollinator protection, as well as reduce hazards of pest management activities to people and the environment. Cooperative Extension staff can assist with the development of farm-specific IPM programs, and financial support for transitioning to IPM is available through the USDA Natural Resources Conservation Service (NRCS).

Healthy, diverse pollinator habitat has the elements needed to encourage other beneficial insects, such as the predators or parasites of pest insects. The use of pesticides, however, often creates pest resurgences by eliminating natural enemies. Whereas pests have evolved to quickly recolonize and multiply in new areas of habitat, pollinators and predators may take years to return to pre-spray levels. In the weeks after treating a field with insecticides, the pests will return but the pollinators, as well as the predators and parasites of pests, may not.

# Reducing the Risk from Insecticides

If pesticides must be used, the following best management practices can help minimize their risk to pollinators and other beneficial insects.

## Active Ingredients and Specificity

Use active ingredients that have the least impact on bees. Some insecticides, such as *Bacillus thuringiensis (Bt)*—or var. *kurstaki (Btk)*—for moth caterpillars, are targeted to particular pests and have little or no impact on native bees.

Other active ingredients, however, are very deadly to bees. [Note: Specific lists of the toxicity of various active ingredients for bees can be found in Hooven et al. (2013), see Appendix D.] These are known as broad-spectrum insecticides because of their general toxicity to all insects. These broad-spectrum insecticides should be used only when field scouting indicates a significant pest problem, not on a calendar spray schedule, and then in ways that are safe for bees (see below). Also, never apply more than the label recommendation.

Keep in mind that some insecticides approved for organic agriculture can cause harm to bees (e.g., spinosad). For an overview of selecting organic pesticides to minimize toxicity to bees, see the link in Appendix D to the Xerces Society's *Organic-Approved Pesticides* fact sheet.

Insecticide applications may kill pollinators and other beneficial insects. If insecticides must be used, drift onto adjacent habitat can be minimized if sprays are applied close to the ground and insecticide-free buffers are maintained. (Photograph courtesy of the NRCS.)

## Drift Control

Consider the droplet size and the potential for drift onto adjacent habitat when applying insecticides. Sprays with coarser droplet sizes pose a greater hazard than fine sprays if they come in direct contact with an insect. However, fine sprays have a greater tendency to drift outside of a target area.

To minimize drift from the site of application, apply insecticides from the ground, not from an aircraft, and leave a 25-foot-wide pesticide-free buffer around the edge of the target spray area, or at least as much of a buffer as possible. Apply insecticides when wind speed is 9 mph or less, wind direction is away from a sensitive area, and use a drift reduction technology if applicable. If the wind is too calm, this may indicate a temperature inversion. Do not apply during a temperature inversion, which may be determined by noting the presence of ground fog, light variable wind (below 3 mph typically), or layering of smoke and dust.

Crop dusting from the air often results in drift over bee nest sites and forage. At the very least, be sure that sprayers are off when turning over non-crop areas adjacent to targeted fields. (Photograph by Joel Sartore, www.joelsartore.com.)

If drift from adjacent land is a concern, windbreaks can provide protection from pesticide drift. Multiple rows of small-needled evergreens such as spruce, juniper, fir and arborvitae are effective at capturing spray drift. These plants are best for windbreaks designed to limit pesticide drift because they do not provide forage for bees and so will not be attractive to bees. For advice on creating windbreaks designed to reduce pesticide drift, see the link in Appendix D to the *Inside Agroforestry* article “Windbreaks designed with pollinators in mind.”

## Formulation

Use formulations that are safest for bees. Insecticide formulations such as dusts, wettable powders, and flowable formulations are more hazardous to bees than emulsifiable concentrates, soluble powders, or granular formulations.

Micro-encapsulated products, if formulated using a traditional broad-spectrum insecticide, offer a unique threat to developing larvae in the nest because foraging bees may mistake them for pollen and bring them back to the nest where the capsules will slowly release their active ingredients and poison the larvae.

## Timing of Application

Insecticides that are toxic to bees should never be applied to a crop in bloom, or to adjacent blooming plants. It is also important to remember that the native bees that pollinate a crop may be foraging on cover crops or adjacent flowers before and after a crop comes into bloom.

Insecticides that are *less* toxic to bees or degrade quickly may be applied over flowers when pollinators are not active, such as in the late evening, immediately after bees stop foraging for the day. Keep in mind that even if insecticides do not outright kill the bees visiting the crop, insecticide residue left on plants still may have a negative impact, especially on smaller bees.

Applications of certain long-lasting systemic insecticides (e.g., imidacloprid, clothianidin) can have a long residual period within plants. Although an application may be made long before pollinators become active during bloom, nectar and pollen can contain small amounts of insecticide residue that can be harmful to bees.

Additional information about the residual toxicity of insecticides, the amount of time after an application that a particular pesticide remains toxic to bees, can be found in Hooven et al. (2013). Additional details about the unique threats posed by systemic insecticides can be found in Hopwood et al (2014) (See Appendix D).

## Temperature and Dew

Temperature and dew have a significant effect on the duration of toxicity of most insecticides. In general, cooler temperatures result in much longer periods of toxicity, and dewy nights cause the insecticide to remain wet on the foliage and be more toxic to bees the following morning. In general, it is better to apply insecticides when the weather is warmest, and at least an hour after sunset because bees are active until dark on hot days.

## Label Guidelines

Pesticide label guidelines are written primarily to protect honey bees. Following these guidelines will *help* to protect wild native bees, but they are not written specifically with them in mind. Native bee activity often extends beyond that of honey bees. Some native bees are active at or before dawn, such as squash bees (an important pollinator of melons and squash plants). Bumble bees are active from early in the morning until sunset, much longer than honey bees. Be sure all bee activity (usually after dusk) has ceased before applying a product.

Guidelines for protecting honey bees also require that beekeepers move hives away from spray areas or shut the bees in and cover their hives during spraying operations, and that pesticide applicators avoid spraying over apiaries and alkali bee beds. Such protective measures are not possible with wild bees. Native bees continue to forage—or even nest—in the sprayed area throughout the entire time the area is toxic, which may last from an hour to more than two weeks. If crop flowers or flowering vegetation near the crop (e.g., clover in orchard understory) is in bloom, assume that bees will be foraging.

## Consider Non-Pesticide Solutions to Pest Problems

Alternatives to pesticides should be considered. For example, planting crop varieties that are resistant to pests will lessen the need for insecticides. Also look for lures, baits, and pheromones for mating disruption. Floating row covers can be used over leafy crops to reduce pests, and fruit bags or kaolin clay are barriers that can protect tree fruit. These tools are very targeted and do not put poisons onto the land. New products continue to be developed and are solving more and more pest problems.

Habitat that benefits pollinators can also support beneficial insects that contribute to crop pest control. Predators and parasitoids of crop pests rely on non-crop habitat for supplementary food sources in the form of pollen or nectar, as well as for shelter and overwintering sites. Consider implementing specific strategies to support beneficial insects, in order to benefit from their contributions to pest control (See *Farming with Native Beneficial Insects*, Appendix D).

Blue orchard bees pollinating almond blossoms. Orchards should not be sprayed while in bloom to avoid harming pollinators. (Photographs by Derek Artz, Utah State University USDA–ARS Logan Bee Lab.)

# Case Study: Protecting Pollinators While Fighting an Invasive Pest

There is a strong history of conservation management in Mike Omeg's family. As the fifth generation to farm on his family's land, Mike takes the land's history, and its conservation, seriously. Currently, Omeg Orchards grows 350 acres of sweet cherries in The Dalles, Oregon. Wild bees first came across Mike's radar through his approach to pest management, which included establishing insectary plantings to support beneficial predatory insects. The plantings did their job, drawing in lacewings, lady beetles, and other beneficial insects that suppressed a number of cherry pests, allowing Mike to reduce insecticide sprays. The plantings also attracted pollinators, and Mike began to notice that trees near the plantings had increased yield due to improved pollination. Soon after, Mike worked to establish additional habitat on the farm to support both bees and beneficial insects, installing insectary plantings and hedgerows near orchards, along roadsides, and near outbuildings.

Pollinator and beneficial insect protection from pesticides has been a key component of Mike's IPM program. Mike could keep his key pests under damaging thresholds by utilizing products such as insect growth regulators or *Bt* that were not harmful to bees or beneficial insects. Wild bees and beneficial insects were more abundant than ever. But with the arrival over four years ago of a new invasive pest, spotted wing drosophila (*Drosophila suzukii*), pest management strategies had to change. Unlike other fruit flies that need damaged fruit in order to lay their eggs and have only one generation a year, spotted wing drosophila (SWD) can cut into undamaged fruit to inject their eggs (introducing fungal diseases in the process) and can complete several generations during the growing season. Unfortunately, there is limited knowledge of the biology of SWD, so its susceptible life stages, the best ways to monitor it, and damage thresholds are not fully known. As a result, IPM for SWD is still in early stages. In order to control SWD, Mike and other tree fruit and small fruit growers across the country have had to resort to products that are much more harmful to bees. Before the arrival of SWD, Mike hadn't applied pyrethroids, a group of insecticides highly toxic to bees, on his land for 20 years.

With the arrival of SWD, Mike was forced to adapt to less pollinator-friendly pest management strategies. Despite the obstacles of SWD control, Mike has worked to reduce risks to pollinators whenever possible. Although he must sometimes use chemical products that are toxic to bees, he reduces exposure to bees by spraying at night when bees are not active, and by not applying products during the cherry bloom. He has also started to mow down any blooming plants within the orchards before spraying for SWD, so bees are not exposed by drift onto non-crop flowers. Mike is focusing on encouraging early blooming shrubs like golden currant and serviceberry, as well as late blooming wildflowers like goldenrod and sunflowers to support bees. These plants all bloom outside the period of application to treat to SWD. Plantings in the understory of non-bearing orchards, which are not treated for SWD, also serve as a refuge for bees.

Though the situation is less than ideal, Mike's steps to protect pollinators and beneficial insects despite heavy pest pressure from SWD mean that he still sees some bees on the farm. He is hopeful that IPM tools will soon become available that will allow him to return to a more bee-friendly system.

Nuttall's sunflowers draw pollinators and increase yields in adjacent trees at Omeg Orchards, in The Dalles, Oregon. (Photograph by Mace Vaughan, The Xerces Society.)

Long-horned bee using Nuttall's sunflower, a late blooming resource, at Omeg Orchards. Sunflowers bloom outside the period of application to treat spotted wing drosophila. (Photograph by Mace Vaughan, The Xerces Society.)

Despite the challenges of novel pests, Omeg Orchards still practices IPM and supports native bees with habitat plantings. (Photograph by Mace Vaughan, The Xerces Society.)

Plains coreopsis in bloom. (Photograph by Jennifer Hopwood, The Xerces Society.)

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# Technical and Financial Assistance

The upfront costs of establishing pollinator habitat, such as a hedgerow or a meadow planting, can seem daunting. However, there are resources available to help with habitat establishment. The USDA's Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) provide financial assistance to support conservation efforts for pollinators and other wildlife on working agricultural lands. Conservation programs such as the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program, and Conservation Reserve Program all can be used to help agricultural producers establish pollinator-friendly native species plantings. The NRCS also provides free technical assistance to land owners and managers, and can help develop conservation plans to address any resource or habitat concerns. For information on conservation programs or technical assistance, contact your local NRCS, FSA, or a local conservation district office. The office nearest you can be located at http://offices.sc.egov.usda.gov/locator/app.

Land trusts also may be able to provide financial support for land owners with an interest in permanently protecting habitat and working agriculture on their land. Nonprofit land trusts will often work in tandem with NRCS to construct voluntary land preservation agreements known as conservation easements which meet the needs of the landowner while also protecting natural resources. Visit the Land Trust Alliance (https://findalandtrust.org/) or LandScope America (http://www.landscope.org/connect/find/) websites to find a land trust near you.

Increasingly, research is demonstrating that, with time, pollinator habitat can provide returns on initial investments. Researchers from the University of California–Berkeley found that hedgerow plantings support a higher abundance and diversity of native bees than weedy, unmanaged field borders; bees are also more abundant in fields with adjacent hedgerows. The long-term benefits that hedgerows provide, including crop pollination and contributions to crop pest management, can offset the initial costs of establishing a farm hedgerow within 10 years. Establishment costs are offset sooner if the hedgerow was financed with cost-share assistance from the USDA–NRCS.

In Michigan, researchers established wildflower plantings adjacent to blueberry fields and monitored bee visitation in the crop and plantings as well as blueberry pollination and yield for four years following habitat installation. As the habitat became established, numbers of bees in the blueberry fields adjacent to the wildflowers increased. Though no differences were observed in years one and two, fields adjacent to wildflower plantings had higher numbers of bees, and greater blueberry yields, in years three and four. Farmers that received cost share assistance with the installation of the planting saw a profit from the planting within 3–4 years, and unsubsidized plantings resulted in profits within 4–5 years.

In addition to the long-term benefits of supporting pollinators, habitat integrated into farms can also provide other benefits, including retention of soil and nutrients, in a cost-effective way.

Pollinator habitat adjacent to apple orchard. (Photograph by Don Keirstead, New Hampshire NRCS.)

# 10

# Conclusion

Each farm has different opportunities and conditions for supporting native bees and, when managed with pollinators in mind, farmlands can become havens for these useful, important insects. The first steps are to learn to identify the bees, nest sites, and forage already present on a farm. Knowing where native bees occur and their basic biology will help growers to make simple changes in farm management. These changes can have profound benefits to the local bee community. Beyond these first steps, farmers can then work to enhance native bee populations, using their knowledge to determine how and where to provide the resources needed for bees to thrive.

Taking action to protect or provide habitat for native bees helps the bottom line. In the past few years, difficulty obtaining honey bees for the pollination of almond orchards has received much publicity, and, more recently, a myriad of stressors has resulted in significant annual losses of honey bees across the United States. Any steps taken by growers of almonds and other bee-pollinated plants to reduce their reliance on a single pollinator ultimately increases the grower's economic security.

Fuzzy-horned bumble bee pollinating black raspberries in Oregon. (Photograph by Mace Vaughan, The Xerces Society.)

We hope these guidelines inspire growers and other conservationists to take action to protect biodiversity in farm landscapes. We also hope this information encourages people to think broadly about the added benefits provided by hedgerows, restored streams, grassed waterways, and other often-overlooked natural areas around the farm when habitat needs of pollinators are included. Almost any undisturbed habitat within a stone's throw of a field may be providing the nest sites and floral resources that sustain crop-pollinating native bees. These habitat patches should be valued for supporting the work of these important insects.

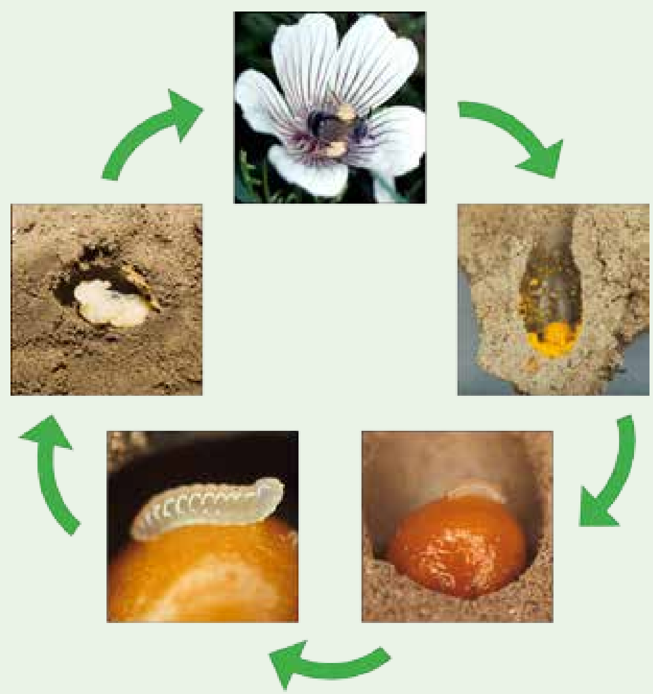
Bumble bee on birdsfoot trefoil. (Photograph by Margo Conner, The Xerces Society.)

# Appendix A

## Natural History of Native Bees

Bees are considered the most important group of pollinators for a simple reason: female bees collect nectar and pollen from flowers to take back to their nests as food for their offspring; and, in doing this, carry large quantities of pollen from flower to flower. A single female bee may visit tens or even hundreds of flowers on a foraging trip, actively gathering and moving pollen. Female bees have special structures on their legs and bodies to carry pollen, and some of the pollen brushes off when they visit other flowers. Although male bees don't actively collect pollen, they visit flowers to drink nectar and to seek out females, and may deposit pollen incidentally. As bees visit flowers, plants are pollinated.

**The Metamorphosis of Solitary Bees**



Solitary ground-nesting bees, such as this mining bee, spend about 11 months in their underground nest cells before emerging as an adult that lives for only a few weeks. Different bee species vary in their time of adult emergence. (Photographs by Dennis Briggs.)

### Life Cycle of Bees

Like a butterfly, a bee undergoes complete metamorphosis, passing through four stages during its lifetime: egg, larva, pupa, and adult. It is only the last of these stages, the adult, which we see and recognize as a bee. During the first three stages, the bee is inside the brood cell of the nest. How long each stage lasts varies widely by species, and is often defined by whether the bee is solitary or social.

### Generalist or Specialist?

Bees can be divided into two loose groups according to their foraging habits. Generalists are bees that gather nectar and pollen from a wide range of flower types and species. The majority of bees, including the social species, are generalists. Specialists, on the other hand, rely on a single plant species or a closely-related group of plants for pollen. The life cycle of these bee species is often closely tied to their host plants; adults will emerge from their brood cells when the plants are flowering.

## Solitary or Social?

Bees can also be divided into two groups according to lifestyle: social or solitary. Contrary to the stereotypical image of a bee living with thousands of sisters in a hive, relatively few species are, in fact, truly social. Social bees live as a colony in a nest with one reproductive female and share the labor of building the nest, caring for offspring, and foraging for pollen and nectar. The truly social bees in the United States are the non-native European honey bee (*Apis mellifera*) and the bumble bees (genus *Bombus*; about 45 species), although many species of sweat bees also exhibit some level of social behavior. Nearly all of the rest of the approximately 4,000 species of bees in the United States are solitary. Each solitary female creates and provisions a nest on her own, without cooperation from other bees. Although solitary bees often will nest together in great numbers when a good nesting area is found, these bees are not cooperating.

### Solitary Bees

Solitary bees generally live for about a year, although we see only the active adult stage, which lasts about three to six weeks. These insects spent the previous 11 months hidden in a nest, growing through the egg, larval, and pupal stages. After emerging from the nest, a male bee typically loiters around a nesting area or a foraging site hoping to mate with a female. After a female bee emerges, she mates and then spends her time creating and provisioning a nest in which to lay eggs.

Solitary bees nesting together in a commercial nesting block. (Photograph by Eric Lee-Mäder, The Xerces Society.)

Female native bees have amazing engineering skills, going to extraordinary lengths to construct a secure nest. About 30% of solitary bee species use abandoned beetle burrows or other tunnels in snags (dead or dying standing trees). Alternatively, they may chew out a nest within the soft central pith of stems and twigs. The other 70% nest in the ground, digging tunnels in bare or partially-vegetated, well-drained soil.

Each bee nest usually has several separate brood cells in which the female will lay her eggs. The number of cells varies by species. While some nests may have only a single cell, most have 10 or more. Female wood-nesting bees make cells in a single line that fills the tunnel. Females of ground-nesting species may dig complex, branching tunnels. To protect the developing bee, the cell may be formed or lined with waxy or cellophane-like secretions, pieces of leaves or petals, mud, or chewed-up wood.

Before she closes each cell, the bee provisions it with food for her offspring. She mixes together nectar and pollen to form a loaf of “bee bread” inside the brood cell (page 61). She then lays an egg in the cell, usually on the loaf, and seals the cell. When she has completed and sealed each of the cells in the nest, the bee will cap the nest entrance and leave.

A female solitary bee may lay up to 30 eggs in her life. Each egg resembles a tiny white sausage. One to three weeks after an egg is laid, it hatches and a white, soft-bodied, grub-like larva emerges. All of the bee's growth occurs during this larval stage. Feeding on the bee bread, the larva grows rapidly for six to eight weeks before changing into a pupa. During the dormant pupal stage, which may last eight or nine months, the bee transforms into its adult form. When it emerges, the adult bee is fully grown.

## Social Bees

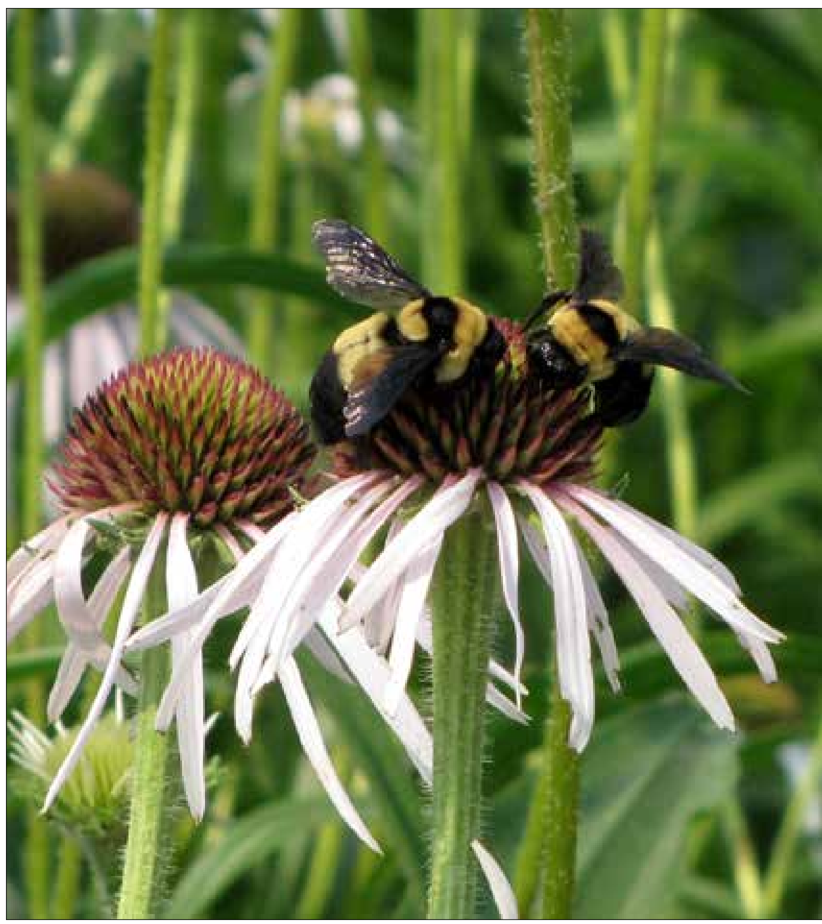
Most social bees live very much like solitary bees—digging and provisioning a nest in the ground before sealing it and abandoning it—except that they have a few helpers. Bumble bees are the best known social bees native to the United States. Like the European honey bee, bumble bees live in colonies, share the work of foraging and nest construction, and produce many overlapping generations through the year.

However, unlike honey bees, bumble bee colonies are seasonal. At the end of the summer, most of the bees in the colony die, leaving only a few fertilized queens to hibernate through the winter. In the spring, each surviving queen will start a new nest, which may eventually grow to include dozens to hundreds of individuals, depending on the species. Bumble bees are often the first bees active in late winter and the last bees active in the fall. Therefore, a wide range of plant species must be available all season-long to support the colony.

Bumble bees are generalist foragers, visiting a diversity of flowers, although a few groups of flowers are especially important to them, such as willows early in the year, lupines in the summer, and goldenrod in the fall. Bumble bees also can perform "buzz pollination," in which they grab onto the anthers of certain flowers and vibrate their flight muscles—with an audible buzz—causing the flower to release pollen from deep pores in the anthers.

Bumble bees need a suitable cavity in which to nest. Sometimes they build nests above ground, such as in hollow trees or walls, or under a tussock of grass, but generally they nest underground. Abandoned rodent holes are common nest sites, as this space is easily warmed and already lined with fur. The queen creates the first few pot-like brood cells from wax, lays eggs, and then forages to provide them with pollen and nectar. It will take at least a month for her to raise this first brood. When they emerge, these bees become workers. They take on the task of foraging and help the queen tend the growing number of brood cells.

Each worker may live for a couple of months. As the queen continues to lay eggs, the colony grows steadily through the summer. At the end of summer, new queens and drones will emerge and mate. When the cooler weather of fall arrives, most of the bees, including the old queen, will die, leaving only the new, mated queens to find appropriate sites in which to hibernate through the cold months.



Bumble bees are the only truly social bees native to the United States, with over 40 species in North America. Above, two bumble bees are pollinating a purple coneflower. (Photograph by Jennifer Hopwood, The Xerces Society.)

# Appendix B

## Plants for Bees

### Example Wildflower Meadow Seed Mix—Northeast Region

The seed mix below is an example of what you might consider planting to provide pollinator habitat on one acre in the Northeastern region. For larger areas, increase the rate accordingly. The mix is designed to provide season-long pollen and nectar resources on any sunny, mesic to slightly dry upland site. The species included are usually available from commercial producers.

| COMMON NAME | SCIENTIFIC NAME | % OF MIX | SEEDS/ FT² | LBS/ AC. | BLOOM TIME |
|---|---|---|---|---|---|
| Golden Alexanders | *Zizia aurea* | 3% | 1.8 | 0.41 | Early |
| Wild blue indigo | *Baptisia australis* | 0.2% | 0.12 | 0.2 | Early |
| Wild lupine | *Lupinus perennis* | 0.3% | 0.18 | 0.49 | Early |
| Smooth penstemon | *Penstemon digitalis* | 10% | 6 | 0.14 | Early–Mid |
| Butterfly milkweed | *Asclepias tuberosa* | 1.5% | 0.9 | 0.56 | Mid |
| Dotted mint | *Monarda punctata* | 15% | 9 | 0.26 | Mid |
| Lavender hyssop | *Agastache foeniculum* | 8% | 4.8 | 0.2 | Mid |
| Marsh blazing star | *Liatris spicata* | 0.5% | 0.3 | 0.13 | Mid |
| Purple coneflower | *Echinacea purpurea* | 8% | 4.8 | 1.98 | Mid |
| Virginia mountain mint | *Pycnanthemum virginianum* | 10.5% | 6.3 | 0.05 | Mid |
| Wild bergamot | *Monarda fistulosa* | 15% | 9 | 0.31 | Mid |
| New England aster | *Symphyotrichum novae-angliae* | 5% | 3 | 0.11 | Late |
| Showy goldenrod | *Solidago speciosa* | 3% | 1.8 | 0.05 | Late |
| Big bluestem | *Andropogon gerardii* | 5% | 3 | 1 | — |
| Indian grass | *Sorghastrum nutans* | 5% | 3 | 0.96 | — |
| Little bluestem | *Schizachyrium scoparium* | 10% | 6 | 1.86 | — |
| **TOTALS** | | **100%** | **60** | **8.71** | |

#### Find the Perfect Mix for Your Region

See Appendix D for links to regional Habitat Installation Guides and a downloadable seed mix calculator. Additionally, specially designed, Xerces-approved regional seed mixes are featured on the Xerces Society's website at: http://www.xerces.org/pollinator-seed/.

# Example Hedgerow Plant List—California

The following list represents an example of what you might plant to create a native hedgerow in California. Most of these species are commonly available from local native plant nurseries. For other additional information about installation of hedgerows, see the Habitat Installation Guides (Appendix D).

| COMMON NAME | SCIENTIFIC NAME | MAX HEIGHT | WATER NEEDS | NOTES |
|---|---|---|---|---|
| **Early Season Blooming Species** | | | | |
| California lilac | *Ceanothus 'Concha'* | 4′ | L | Tolerates clay soils |
| Frosty blue California lilac | *Ceanothus 'Frosty Blue'* | 8′ | L | Tolerates clay soils |
| McMinn manzanita | *Arcostaphylos 'McMinn'* | 5′ | L | Tolerates clay soils |
| Narrowleaf willow | *Salix exigua* | 10′ | H | Wetland-riparian to semi-riparian species |
| Oregon grape | *Mahonia aquifolium* | 5′ | L | Drought-tolerant, but also tolerates semi-riparian conditions |
| Red willow | *Salix laevigata* | 20′ | H | Wetland-riparian to semi-riparian species; tolerates clay soils |
| Western redbud | *Cercis occidentalis* | 15′ | L | Drought-tolerant, but also tolerates semi-riparian conditions |
| **Early–Mid Season Blooming Species** | | | | |
| Blue elderberry | *Sambucus nigra* var. *cerulea* | 15′ | M | Host plant for the endangered Valley Elderberry Longhorn Beetle; tolerates semi-riparian conditions |
| California buckthorn | *Frangula californica* | 5′ | L | |
| Mule's fat | *Baccharis salicifolia* | 8′ | M | Wetland-riparian to semi-riparian species |
| Showy penstemon | *Penstemon spectabilis* | 3′ | L | |
| Toyon | *Heteromeles arbutifolia* | 12′ | L | Can be an alternate host of fire blight |
| **Mid Season Blooming Species** | | | | |
| California buckwheat | *Eriogonum fasciculatum* | 2.5′ | L | Extremely drought tolerant |
| California wildrose | *Rosa californica* | 8′ | M | Tolerates clay soils; drought-tolerant, but also tolerates semi-riparian conditions; can be a host for spotted wing drosophila |
| Cleveland sage | *Salvia clevelandii* | 3′ | L | Requires good drainage |
| Hollyleaf cherry | *Prunus ilicifolia* | 15′ | M | |
| Narrowleaf milkweed | *Asclepias fascicularis* | 1.5′ | M | Sow seeds individually or transplant larger than plug-sized; host for monarch butterfly; tolerates clay soils, wet, or dry conditions |

(*continued on next page*)

Bumble bee on dotted mint (*Monarda punctata*). Also known as "spotted beebalm", dotted mint attracts a variety of pollinators and beneficial insects. (Photograph by Don Keirstead, New Hampshire NRCS.)

| COMMON NAME | SCIENTIFIC NAME | MAX HEIGHT | WATER NEEDS | NOTES |
|---|---|---|---|---|
| **Mid–Late Season Blooming Species** | | | | |
| Big saltbush | *Atriplex lentiformis* | 20′ | L | Tolerates clay soils; can be extremely drought-tolerant |
| California fuchsia | *Epilobium canum* | 3′ | L | |
| Common buttonbush | *Cephalanthus occidentalis* | 15′ | M | Wetland-riparian or semi-riparian species; tolerates clay soils |
| Gumplant | *Grindelia camporum* | 4′ | L | Tolerates wet or dry conditions |
| Nettleleaf giant hyssop | *Agastache urticifolia* | 4′ | M | Tolerates clay soils; tolerates semi-riparian conditions |
| **Late Season Blooming Species** | | | | |
| California aster | *Symphyotrichum chilense* | 5′ | L | Establishes better from transplant than seed; tolerates clay soils; tolerates wet or dry conditions |
| Canada goldenrod | *Solidago canadensis* | 3′ | M | Establishes better from transplant than seed; tolerates wet or dry conditions |
| Coyotebrush | *Baccharis pilularis* | 10′ | L | Dioecious; use male plants to avoid unwanted seeding; extremely drought-tolerant |
| Dwarf coyotebrush | *Baccharis pilularis 'Pigeon Point'* | 2′ | L | Dioecious; use male plants to avoid unwanted seeding; extremely drought-tolerant |

*Notes:*
Water Needs abbreviations: L = low, M = medium, H = high

## A Friendly Reminder

Before ordering, please ensure that all plants or seeds purchased for pollinator habitat have ***NOT*** been treated with systemic insecticides!

This newly-planted hedgerow in California includes a mix of forbs and shrubs—including California poppies, California phacelia, and coyotebrush—that provide continuous forage and nesting habitat throughout the growing season. (Photograph by Jessa Kay Cruz, The Xerces Society.)

# Cover Crops for Pollinators

The following list provides examples of cover crops that have value to wild bees as well as honey bees. Most of these species are commonly available as seed from local seed dealers. See Appendix D for additional resources about cover crops.

| COVER CROP | LIFECYCLE |
|---|---|
| Alfalfa | *Perennial* |
| Birdsfoot trefoil | *Perennial* |
| Buckwheat | *Annual* |
| Canola | *Annual* |
| Carrot | *Biennial* |
| Chickpea | *Annual* |
| Cilantro | *Annual* |
| Clover, berseem | *Annual* |
| Clover, crimson | *Annual* |
| Clover, kura | *Perennial* |
| Clover, red | *Perennial* |
| Clover, rose | *Annual* |
| Clover, strawberry | *Perennial* |
| Clover, white | *Perennial* |
| Cowpea | *Annual* |
| Dill | *Annual* |
| Fava bean | *Annual* |
| Flax | *Annual* |
| Kale | *Biennial* |
| Mustard, tame | *Annual* |
| Partridge pea | *Annual* |
| Phacelia | *Annual* |
| Radish | *Biennial* |
| Safflower | *Annual* |
| Sainfoin | *Perennial* |
| Soybean | *Annual* |
| Sunflower | *Annual* |
| Sunn hemp | *Annual* |
| Sweet clover | *Biennial* |
| Turnip | *Biennial* |
| Vetch, chickling | *Annual* |
| Vetch, common | *Annual* |
| Vetch, hairy | *Annual* |
| Vetch, purple | *Perennial* |

Small sweat bee pollinating canola blossom. (Photograph by Mace Vaughan, The Xerces Society.)

A leafcutter bee foraging on white clover cover crop between rows of raspberry. (Photograph by Mace Vaughan, The Xerces Society.)

## Garden Plants

This list of garden plants includes an assortment of plants, only some of which are native to North America. These plants are suitable for flower borders but not for inclusion in areas of native habitat.*

Some decorative garden plants are excellent sources of forage for bees in flower borders or insectary strips. Above, a long-horned bee pollinates a purple coneflower; below, a sunflower bee on a coreopsis bloom. (Photographs by Mace Vaughan, The Xerces Society [above], and Jennifer Hopwood, The Xerces Society [below].)

| COMMON NAME | GENUS NAME |
|---|---|
| Aster | *Symphyotrichum* |
| Basil | *Ocimum* |
| Bee balm | *Monarda* |
| Blanketflower | *Gaillardia* |
| Blazing star | *Liatris* |
| Borage | *Borago* |
| California poppy | *Eschscholzia* |
| Catmint | *Nepeta* |
| Coreopsis | *Coreopsis* |
| Cosmos | *Cosmos* |
| Giant hyssop | *Agastache* |
| Globe gilia | *Gilia* |
| Hyssop | *Hyssopus* |
| Joe Pye weed | *Eupatorium* |
| Lavender | *Lavandula* |
| Lupine | *Lupinus* |
| Marjoram | *Origanum* |
| Milkweed | *Asclepias* |
| Penstemon | *Penstemon* |
| Phacelia | *Phacelia* |
| Purple coneflower | *Echinacea* |
| Rosemary | *Rosmarinus* |
| Rosinweed | *Silphium* |
| Russian sage | *Perovskia* |
| Sage | *Salvia* |
| Sunflower | *Helianthus* |

*Except in the areas within their natural distribution.

*Note:* When choosing plants, avoid hybrid varieties, which were often bred for showy petals at the expense of nectar or pollen production.

# Appendix C

## Pollinator Habitat Checklist

### Forage Habitat

EXISTING FUTURE

☐ ☐ **Native plant field borders, buffer strips**
Borders with multiple species of native wildflowers can provide floral resources for pollinators.

☐ ☐ **Hedgerows**
Native shrubs and small trees can provide floral resources for pollinators, as well as nesting sites.

☐ ☐ **Insectary plantings**
Insectary plantings can support pollinators within or adjacent to crops, and the flowering can be timed to provide nectar and pollen when most needed to support pollinators.

☐ ☐ **Farm gardens**
Flower gardens planted for their beauty or cut flowers provide yet another source of nectar and pollen for bees.

☐ ☐ **Natural or semi-natural areas**
Woodlots, stream banks, roadsides, or other natural features can support blooming plants that, in turn, support pollinators.

☐ ☐ **Cover crops**
Cover crops help to build soil health, and when allowed to flower, can support pollinators. Growing a mixed cover crop will further ensure a diverse bloom.

☐ ☐ **Vegetative cover in orchard alleys or field roads**
Vegetative cover (e.g., white clover in alleys) can add nutrients to the soil while providing floral resources for pollinators and beneficial insects. If there are concerns about pollinators, particularly honey bees, being distracted from the crop bloom, alleys or roads may be mown when the crop is in bloom.

### Nesting Habitat for Bees

EXISTING FUTURE

☐ ☐ **Untilled areas**
Areas left untilled, such as hedgerows, field borders, woodlots, road edges, stream banks, and conservation areas, as well as unused land around farm buildings and service areas, all can provide nest sites needed by native bees. Poor quality or poorly irrigated land can provide some of the best sites for ground-nesting bees, because many prefer nesting in well-drained, inorganic sand and silt.

☐ ☐ **Hedgerows**
Native shrubs and small trees can provide nesting habitat for bees and likely provide a corridor along which bees can migrate more quickly through the agricultural landscape.

☐ ☐ **Brush piles, snags**
Piles of brush and snags can provide nesting sites for tunnel-nesting bees, and bumble bees may also use brushy areas as nesting habitat.

☐ ☐ **Field borders, buffer strips**
Unmown borders or buffer strips planted with native grasses and wildflowers can provide undisturbed nesting habitat for bumble bees.

# Appendix D

## Resources: Tools, Websites, and Publications

A list of publications and websites (in addition to the Xerces website) that might be useful for implementing pollinator conservation measures, with a focus on materials that are written for the general public or that are available online.

### Tools

**Pollinator Habitat Assessment Form and Guide (The Xerces Society)**
http://www.xerces.org/wp-content/uploads/2009/11/PollinatorHabitatAssessment.pdf
This habitat assessment form and guide enables you to assess specific pollinator habitat features before and after project implementation in both orchard and field crop settings.

**Habitat Installation Guides (The Xerces Society)**
http://www.xerces.org/pollinator-conservation/agriculture/pollinator-habitat-installation-guides/
These regional installation guides include in-depth guidance on installing and maintaining pollinator habitat in the form of wildflower meadow plantings or hedgerows of flowering shrubs, including example seed mixes and plant list recommendations.

**Seed Mix Calculator (The Xerces Society)**
http://www.xerces.org/pollinators-northeast-region/xerces-seed-mix-calculator/
Develop your own pollinator conservation seed mix using this seed rate calculator.

**Streamlined Bee Monitoring Protocol for Assessing Pollinator Habitat (Michigan State University, Rutgers University, University of California–Davis, The Xerces Society)**
http://www.xerces.org/streamlined-bee-monitoring-protocol/
Developed for conservationists, farmers, land managers, and restoration professionals, this guide provides instructions for assessing pollinator habitat quality and diversity by monitoring native bees. Includes an introduction to bee identification, a detailed monitoring protocol, and data sheets for different habitat types.

**Assessing the Pollination of Your Watermelon (The Xerces Society)**
http://www.xerces.org/assessing-watermelon-pollination/
A set of tools that will help you estimate the percentage pollination your watermelon are receiving and the relative contribution of different types of bees to the pollination of your crop.

**Conservation Buffers (US Forest Service Technical Guide)**
www.unl.edu/nac/bufferguidelines/docs/conservation_buffers.pdf
Design guidelines for buffers, corridors, and greenways—including extensive information on hedgerows and windbreaks.

## Websites

**Pollinator Conservation Resource Center (The Xerces Society)**

http://www.xerces.org/pollinator-resource-center/

The Pollinator Conservation Resource Center is your one-stop online source for information about protecting pollinating insects and their habitat, with regional information on plants for pollinator habitat enhancement, habitat conservation guides, nest management instructions, bee identification and monitoring resources, and a directory of pollinator plant nurseries.

**USDA–Agriculture Research Service, Pollinating Insect-Biology, Management, and Systematics Research Lab**

http://www.ars.usda.gov/main/site_main.htm?modecode=54280500

The scientists working at this lab conduct research on native bees as crop pollinators. Their website provides information on identifying bees, pollinator plants, and making nests.

**USDA Natural Resource Conservation Service (NRCS)**

http://www.nrcs.usda.gov

The NRCS provides financial and technical assistance to support conservation efforts for pollinators and other wildlife on farms. For more information on NRCS conservation programs, contact your local NRCS or conservation district office (available at: http://offices.sc.egov.usda.gov/locator/app).

**Lady Bird Johnson Wildflower Center Native Plant Information Network Recommended Species**

http://www.wildflower.org/conservation_pollinators/

The Xerces Society has collaborated with the Lady Bird Johnson Wildflower Center to create plant lists that are attractive to native bees, bumble bees, honey bees, and other beneficial insects, as well as plant lists with value as nesting materials for native bees. These lists can be narrowed down with additional criteria such as state, soil moisture, bloom time, and sunlight requirements.

**Project Integrated Crop Pollination**

http://projecticp.org

This ongoing research project is investigating the performance, economics, and farmer perceptions of different pollination strategies in various fruit and vegetable crops. Visit their website for project news, educational events schedule, publications, and various resources for growers.

## Publications

### Bee Conservation

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Male mining bee emerging from ground tunnel nest. (Photograph by Whitney Cranshaw, Colorado State University, Bugwood.org.)

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Native leafcutter pollinating black raspberries. (Photograph by Mace Vaughan, The Xerces Society.)


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Dotted mint in bloom. (Photograph by Jennifer Hopwood, The Xerces Society.)

# Appendix E

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Pollinators are essential to our environment. The ecological service they provide is necessary for the reproduction of nearly 85% of the world's flowering plants. This includes more than ⅔ of the world's crop species, whose fruits and seeds together provide over 30% of the foods and beverages that we consume. The United States alone grows more than 100 crops that either need or benefit from pollinators. The economic value of insect-pollinated crops in the United States was estimated to be between $18 and $27 billion in 2006. Native insects were responsible for pollinating an estimated $3 billion or more of this total.

With the steady decline in the number of managed honey bee colonies, and unsustainably high annual winter losses, now more than ever we should be concerned about the security of our insect-pollinated crops and our nation's pollinator populations. Habitat conservation and management designed to benefit native bees is one important way in which we can diversify the pollinators we rely upon for agricultural production, while also supporting honey bees in farm landscapes.

These guidelines are designed to help growers and conservationists protect, enhance, and restore habitat for native bees. Inside, you will find advice on how to recognize native bee habitat, what simple changes land managers can make to protect their bees, how to choose sites and plants for restoration, how to construct nests for bees, and much more.

Bring Back the Pollinators
A Xerces Society Conservation Campaign

Xerces Society's Bring Back the Pollinators campaign is based on four principles: grow pollinator-friendly flowers, protect bee nests and butterfly host plants, avoid pesticides, and spread the word. You can participate by taking the Pollinator Protection Pledge and registering your habitat on our nationwide map of pollinator corridors.

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