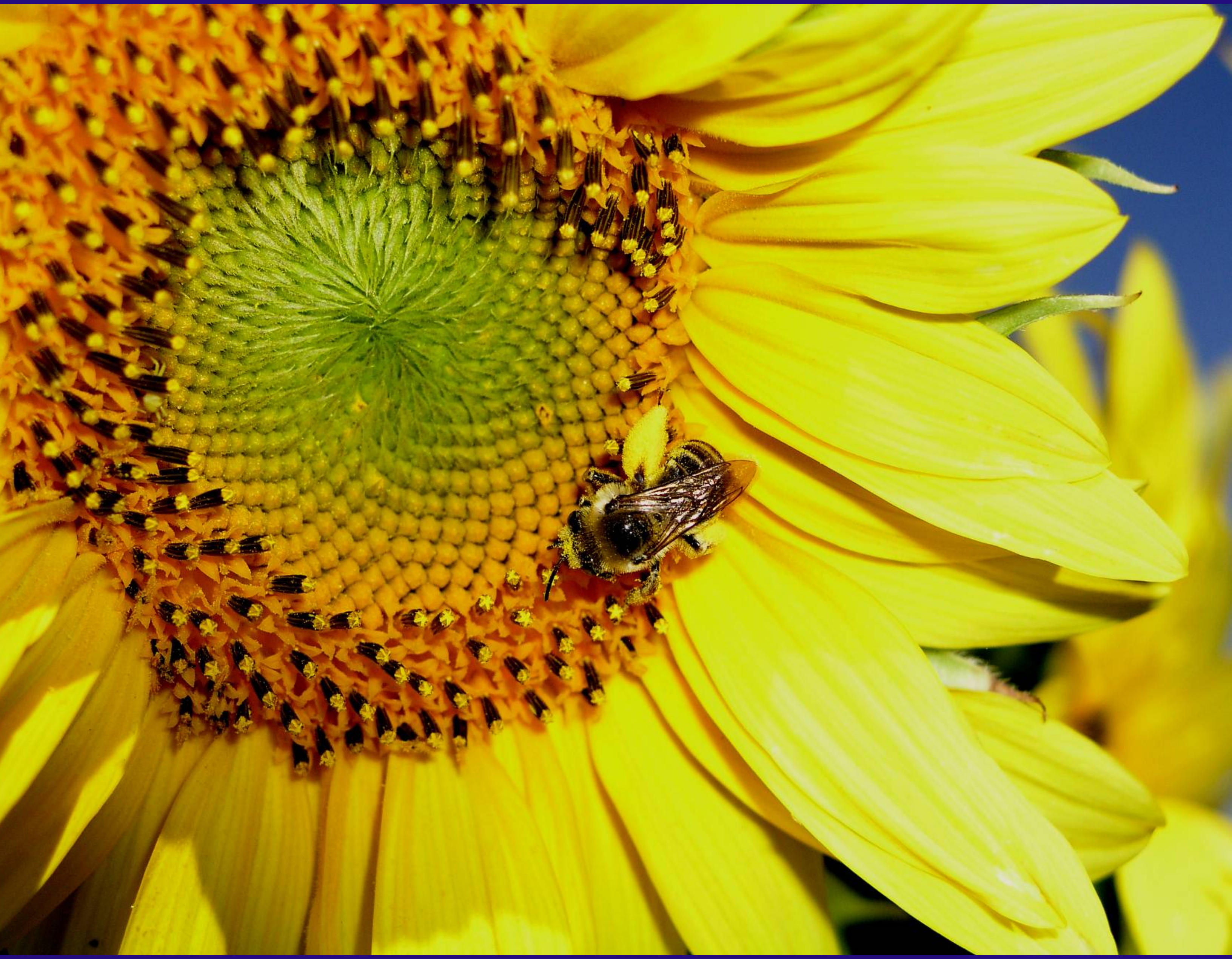
Farming for Bees

Guidelines for Providing Native Bee Habitat on Farms



Mace Vaughan, Matthew Shepherd, Claire Kremen, and Scott Hoffman Black

The Xerces Society for Invertebrate Conservation, Portland, OR

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628 NE Broadway Ste. 200 , Portland, OR 97232 USA

Tel (503) 232-6639 Fax (503) 233-6794 www.xerces.org

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CHAPTER 1
INTRODUCTION

Animals pollinate roughly 35 percent of all crops grown in the world. In North America, bees were responsible for roughly $20 billion in agricultural production in 2000. Most crops are pollinated by managed hives of the European honey bee (*Apis mellifera*). However, the number of managed honey bee hives is declining due to diseases, pests, aggressive strains of honey bees, and, in the winter of 2006-07, Colony Collapse Disorder.

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 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.

Bees, such as this small leafcutter bee, are the most important group of crop-pollinating insects. (Photograph by Mace Vaughan.)

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 native 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!

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.

When honey bees are in short supply, native bees can act as an insurance policy when habitat is present.

NATIVE BEES COMPARED TO HONEY BEES

Native bees pollinate apples, cherries, squash, watermelon, blueberries, cranberries, 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 or cold conditions when honey bees remain in the hive.

Native bees can make honey bees more effective as pollinators of hybrid seed crops by causing them to move more frequently between rows of male and female plants.

Insect-pollinated crops offer more than just food; many are also entrenched in seasonal traditions. Berry picking in summer and pumpkins at Halloween are two examples. (Photograph by Matthew Shepherd.)

Chapter 2: Pollinator Basics

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 quarter of an inch long to bumble and carpenter bees bigger than an inch. While some of these species may look bee-like, with hairy stripes of yellow or white and black, they also may be dark brown, black, or metallic green and 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 percent 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 brood cells, into which she places a mixture of pollen and nectar and lays an egg.

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) small carpenter bees; sweat bees; honey bees and yellow-faced bumble bees; and long-horned bees. (Photographs by Edward S. Ross (2), Sarah Greenleaf, and Mace Vaughan.)

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 eleven months, passing through the egg, larva, and pupa stages before emerging as an adult to renew the cycle the next year.

Only about 45 native bee species in the United States are social bumble bees. Bumble bees nest in small cavities, such as abandoned rodent burrows, that are found under rocks or tussocks of grass. Depending upon the species, their colonies may have a couple-hundred worker bees by mid-summer.

Except for the bumble bees and a few 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' 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.

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 four thousand 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 day's supply of nectar and the colony does not survive beyond the fall.

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, Forestry Images.)

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. The bee-like flies often will hover in the air around flowers, without moving, before quickly dashing off—a behavior seldom seen in true bees.

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

Chapter 3: Pollinator Basics

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. 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 to 2 honey bee hives—approximately 15,000 to 20,000 foragers.

There are many reasons for this increased efficiency. Many native bees, such as mason and bumble bees, are active in colder 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. 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

How native bees benefit crops

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

Fifty-one species of native bees have been observed visiting watermelon, sunflower, or tomato in California.

Over forty-five species of bees have been recorded pollinating berry crops in Maine and Massachusetts.

Sixty-seven species of native bees visit blueberries in Nova Scotia.

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 with both abundant native bees and honey bees had 100 percent seed set.

Research suggests that in the absence of imported honey bees, canola growers in Alberta, Canada make more money from their land if 30 percent 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.

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

Natural habitat close to fields provides important nest sites and forage for the crop-pollinating native bees that visit these sunflowers. (Photograph by Sarah Greenleaf.)

do not require a pollinator to set fruit, buzz-pollination by bees results in larger and more abundant 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.

Native Bees are Diverse and Stable

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

Native Bees May Provide Additional Revenue

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 improvements for 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.

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.

Case Study

Native Bees Thrive on Eastern U.S. Farms

Several Mid-Atlantic states are among the nation's leading producers of insect-pollinated crops, but native bee pollination has been little-studied here, where landscapes and farming practices differ from other parts of the country. Recent research, however, shows native bees to be key crop pollinators in this region, with great potential to help meet the demands of sustainable agriculture in the context of rapidly-developing landscapes.

The research focused on four summer vegetable crops (watermelon, tomato, pepper, and muskmelon) at twenty-nine farms in New Jersey and Pennsylvania. Farms included those under organic and conventional management, as well as farms set in landscapes with little remaining natural habitat cover. Fifty-four species of native bees, from tiny sweat bees to large bumble bees, visit these crops. Different types of crops rely on different suites of bee species, suggesting that a diverse community of native bees is necessary to ensure complete pollination.

For watermelon, tomato, and pepper, native bees were more abundant on crop flowers than were honey bees. Native bees alone were abundant enough to fully pollinate some of these crops. Surprisingly, their contributions were just as great on conventional farms as on organic farms, and at farms with little original natural habitat cover (woodland) remaining in the surrounding landscape.

These findings differ from most previous studies which have found that native bees do not provide sufficient pollination in intensively farmed landscapes. A possible reason for these differences is that in the Mid-Atlantic region, both organic and conventional vegetable farms have small field size, high crop diversity, and abundant flowering weeds. In addition, these Eastern landscapes are characterized by hedgerows and other small patches of natural habitat dispersed throughout even the most intensively used areas. Farm fields were all within a few hundred yards of another habitat type, and this distance is within the flight range of even the smallest sweat bees. The resulting mix of diverse habitat types may provide native bees with the floral and nesting resources they need, even when the overall proportion of natural habitat in the landscape is low.

This work holds great promise for native bee conservation and the sustainability of crop pollination in Eastern landscapes. For the rest of the country, it also provides lessons about the likely value of diverse crop systems and small patches of habitat, such as flowers in field edges or hedgerows, for increasing the role of native bees in crop pollination.

Text and photograph by Rachael Winfree,
Princeton University and University of California, Berkeley
(Photograph of Maple Acres Farm, Plymouth Meeting, PA)

CHAPTER 4: CONSERVATION ACTION

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.

Bees seen entering or leaving holes in the ground are a sure sign of an active nest site. These mining bees were flying on a sunny, April morning. (Photograph by Matthew Shepherd.)

RECOGNIZE RESOURCES ALREADY ON THE FARM

The photos in these guidelines 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

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

Beetle–tunneled snags, like this one, and patches of bare ground are important nesting sites for solitary bees. (Photograph by Matthew Shepherd.)

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 a quarter inch) to larger than a honey bee (three-quarters of an inch).

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 upcoming chapters for details).

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 twenty feet of a crop—will go a long way toward protecting bees nesting or foraging in field margins.

Minimizing the practice of fence-row to fence-row 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.

Flowers providing nectar and pollen are a necessary part of pollinator habitat. (Photograph by Bruce Newhouse.)

A hedgerow of native flowering shrubs flanked by native bunch grasses offers many resources for pollinators. The fallen grass can become a haven for bumble bee nests and the shrubs provide pollen and nectar. (Photograph by Sam Earnshaw, Community Alliance with Family Farmers.)

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.

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 six to twelve inches 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 six inches, 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 (usually native species) 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 percent of bee species nest in the ground and 30 percent use tunnels bored into wood. Bumble bees—a small, but very important group of bees—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.

Case Study

Full Belly Farm, California

Just outside of California's Central Valley, tucked between hills of chaparral and oak savannah, sits Full Belly Farm. The farm's 250 acres support four families, an energetic team of interns and farm hands, and an abundance of native pollinators. By fine-tuning their operation over the past ten years, Full Belly's growers have created a diverse, vibrant, successful farm filled with pollinators, as well as abundant wildlife and other beneficial insects.

The site for this farm was chosen, in part, because of its close proximity to vast acreage of natural habitat. It is tucked into undeveloped hills that serve as an important source of native bees that visit crops and colonize the farm. To help these pollinators get out into the fields, Full Belly has created habitat on the farm that provides forage and nest sites, as well as corridors for the bees to move among the fields and orchards.

The on-farm habitat at Full Belly is a how-to guide for providing forage and nesting resources for native bees in working lands. Cover crops, hedgerows, untended corners, and a diverse, organic cropping system are all tools used by Full Belly to benefit crop pollinators and the bottom line.

You can find cover crops of clover underneath the farm's orchards, as well as buckwheat on their fallow fields in the summer and vetch in the winter. All of these plants provide year-round and abundant forage for crop-pollinating bees. Full Belly has hedgerows designed with insects in mind. A diversity of shrubs and herbaceous plants present a buffet of flowers throughout the growing season, providing a geographic and temporal bridge for the bees to get from one crop to the next.

The crops themselves also provide a steady stream of pollen and nectar. Early blooming peaches, pears and almonds in spring make way for squash, melons, tomatoes and peppers in the summer. The beautiful and forage-rich cut flower gardens add to the abundant and diverse floral resources. In addition, the growers at Full Belly allow many of their crops that do not require a pollinator—such as broccoli, asparagus, and carrots—to flower, thus adding more pollen and nectar to the mix when the plants are no longer productive.

The result of the location and practices is a farm that does not need to rent or manage a single honey bee hive. In the words of Full Belly farmer Paul Muller, it is "a farm that grows all of its own bees."

Text and photograph by Mace Vaughan,
Xerces Society

Chapter 5: Conservation Action

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

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.

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

A nectary strip of sunflowers and mustards planted between two fields supports many beneficial insects, including pollinators, close to crops. (Photograph by Paul Jepson.)

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.

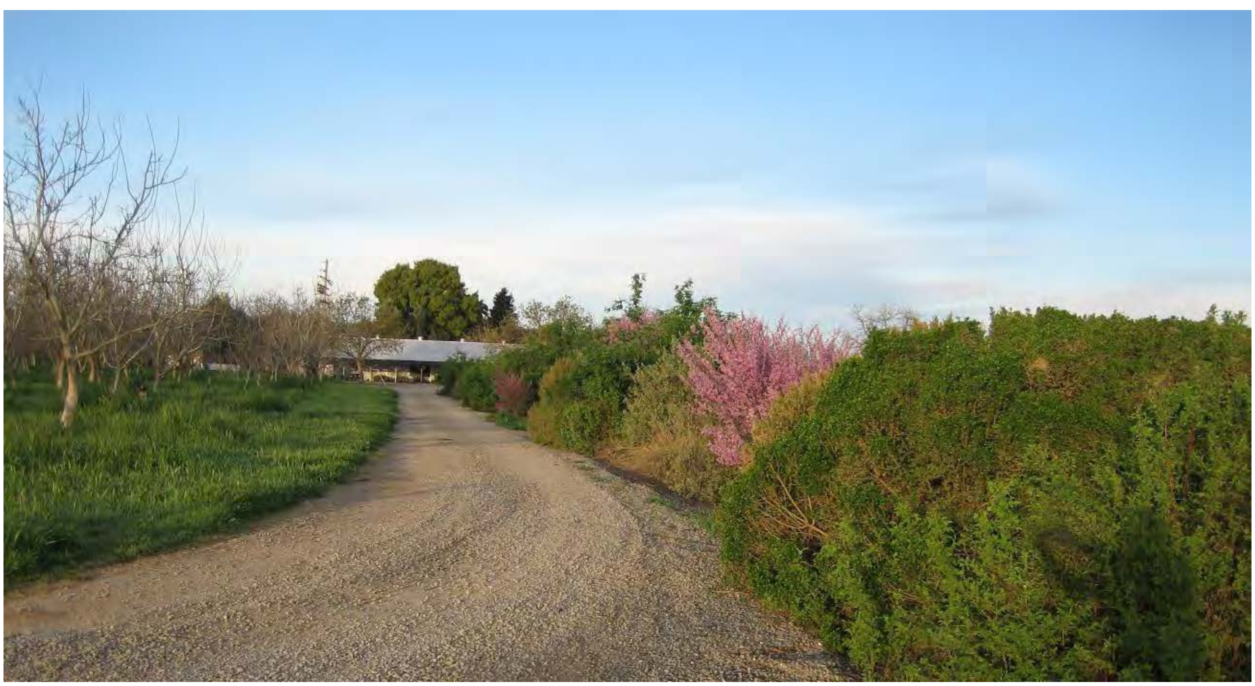
A common problem faced by bees making a living in large stands of apple or cherry trees, for instance, is that the flowers of these crops bloom all at once and then are gone after only a few weeks. This short flowering period, with very little else available the rest of the year, is not conducive to 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 C 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



This pollinator hedgerow planted along a farm road is comprised of a variety of shrubs, including willow, red bud, rose, elderberry, and toyon, that flower from early spring through summer. (Photograph by Katharina Ullmann.)

Peripheral areas along roads, field borders, and streams all can be enhanced to provide the maximum benefit to crop-pollinating native bees. These habitat features also provide connections across the land, so that pollinators can colonize new habitat more efficiently. (Photograph courtesy of the NRCS.)

by native bees.

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.

Distance from fields

The average foraging distance of native bees ranges from about 50 feet 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.

Size of habitat patches

Studies in California provide evidence that around 30 percent 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 percent 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' 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.

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

Carefully located pollinator habitat will support abundant populations of leafcutter bees (pictured here) and other crop pollinators. (Photograph by Edward S. Ross.)

Case Study

Pepco Transmission Lines, Maryland

Pollinators do not recognize land ownership boundaries. This can be an advantage to growers seeking habitat for crop-pollinating bees because neighboring land can harbor these insects. Although often overlooked as a wildlife resource, power transmission corridors cross landscapes—including farms—throughout North America, and with careful management can support valuable pollinator populations.

One example of good power corridor management comes from Maryland. Pepco, the Potomac Electric Power Company, manages a network of transmission lines on 330 miles of rights-of-way (ROW), which covers approximately 10,000 acres in five Maryland counties and the District of Columbia. The ROWs traverse farmland and natural areas, include diverse ecosystems and habitat, and form fingers through many rural, suburban and urban communities.

Pepco manages the ROW to ensure safe and reliable transmission of electricity. However, in doing this they also strive to maximize the habitat value of their land, and their management approach has created miles of open, meadow-like areas that provide great conditions for many bees, butterflies, and other pollinator insects.

This approach to ROW management was sparked, quite literally, by a single tree growing into the wires that caused a major power outage in 1998. Subsequent surveys discovered hundreds of other trees that were growing dangerously close to wires. These events led to a review of ROW maintenance and the development of a new approach to vegetation management, one that removes trees to create low-growing vegetation.

In western Montgomery County, along the Dickerson to Potomac River transmission line, Pepco's meadow management program has created six acres of open, flower-rich habitat. Trees were removed from under the transmission lines, the remaining vegetation mowed to near ground level, and selective herbicides used to prevent rapid regeneration of woody perennials. In the second and subsequent years, all seedlings of taller-growing woody species have been spot treated with a selective herbicide. Preventing regrowth has permitted the dormant seed of annual and perennial flowers and grasses to germinate and grow. In addition, the restored habitat has been enhanced by the introduction of many native butterfly nectar and larva host plants.

A major influence on this program was the decades old partnership between Pepco and the U.S. Fish and Wildlife Service's Patuxent Wildlife Research Center. One of Pepco's rights-of-way passes through the Patuxent reserve and has been managed jointly by Pepco and Patuxent's scientists.

Transmission corridors are perfectly suited to pollinator habitat because power lines and trees are not a safe mix. The approach Pepco has taken to their ROW could be replicated elsewhere.

Text and photograph by Steve Genua, Pepco and Matthew Shepherd, Xerces Society

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.

CHOOSING NATIVE PLANTS

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 they are usually adapted to grow in the local climate and soils and, once established, they require little attention.

The appendices provide specific information on finding appropriate pollinator-friendly plants for restoration projects. Appendix B includes links to national and regional lists of plants that are important sources of forage for bees across the United States. Appendix C lists garden plants, both native and non-native, that are excellent sources of pollen and nectar. 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.

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. Horticultural varieties and hybrids, in contrast, are not always adapted to local conditions and may have been bred to produce showy blooms 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.

Choose flowers that bloom throughout the growing season

Adult bees can be seen anytime between February and November; they have longer seasons in areas

This yellow Oregon grape is attractive to bees, especially bumble bees, and flowers very early in the spring where it occurs. Other good flower colors for bees include blue, purple, violet, and white. (Photograph by Matthew Shepherd.)

Flowers such as goldenrod that bloom late in the season are an important resource for queen bumble bees preparing to hibernate for the winter. (Photograph by Steve Javorek.)

with mild climates. The social bumble bees may be seen in any of these months, whereas the emergence and active adult life of many solitary-nesting 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 that emerge from hibernation to start their nests nearby.

Choose plants that complement a particular crop

The adult life stage of most bees is such that they emerge before crops come into bloom or 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.

Think five years ahead

Planning five or ten years ahead is important to 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

Different insects are able to reach nectar inside different shapes of flowers. Planting a diversity of flowers with a range of shapes will help support a diversity of pollinators. (Photograph by Jeff Owens, Metalmark Images.)

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.

Choose appropriate plants for the site conditions

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 when possible. One way to address this situation is to take notes on the native plants growing wild in similar conditions nearby.

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, Soil and Water Conservation District, 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?

Choose plants with a diversity of color

Bees can see a wide range of colors. Whereas people see a rainbow spectrum from red through violet, bees see from orange to blues and ultraviolet (UV). To a bee, what we see as red appears black. In practical terms, this means that good flower colors for bees are blue, purple, violet, white, and yellow. Some red flowers, such as blanket flower and poppies, have a UV color component and are therefore also attractive to bees.

Choose flowers of different shapes

Bee species vary in size, have different tongue lengths and, consequently, 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. A range of flower shapes supports more bees and other beneficial insects.

Avoid invasive species

Avoid plant species known to be highly invasive. These plants likely will spread and dominate other species, reduce the diversity and value of the habitat, and increase maintenance demands—both in the

Sweat 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.)

habitat patch and elsewhere around the farm. They also may spread beyond the farm and cause problems in neighboring natural areas. Check with your county for any code restrictions on noxious weed species.

Be cautious with rare species

Usually, species are rare for a reason. For example, they may have very specific conditions for establishment or a particular habitat requirement, or they may lack a specific pollinator, which makes them difficult to sustain at a site. If you plan to use locally rare species, seek the knowledge of specialists and be prepared to do a little more work.

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, older varieties of perennials and herbs are the best sources of nectar or pollen. Newer 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 C for garden plant recommendations.

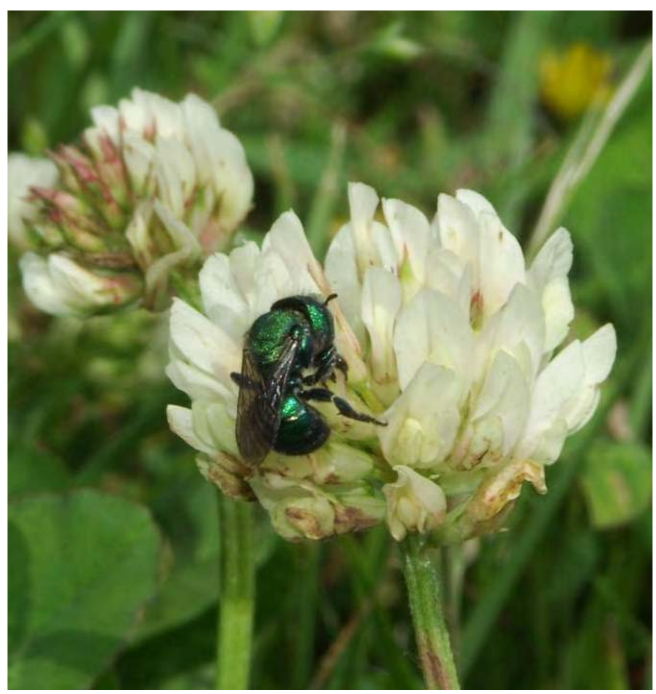
Planting Forage Cover Crops

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 in a ground cover that provides nectar and pollen supporting native bees.

Ideally, the best plants for a cover crop will grow with a low stature and have abundant flowers. These cover crops can also provide several other benefits, such as improving erosion control and soil permeability, fixing nitrogen, discouraging weeds, and harboring beneficial insects. Consult with local nurseries or cooperative extension offices regarding cover crops best suited to a particular crop or area. Some excellent cover crops species include clover, trefoil, vetch, phacelia, buckwheat, and small varieties of yarrow. See Appendix D for sources of more 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.



A leafcutter bee, *Osmia aglaia*, foraging on a white clover cover crop between rows of raspberry. (Photograph by Mace Vaughan.)

CASE STUDY

BUTLER FARM, CALIFORNIA

Lew Butler's farm looks like any other large field in California's Central Valley, recently tilled as if ready to accept seeds for the next rotation of tomatoes or sunflowers. But, when you walk onto the farm you discover changes are afoot, harbingers of good things to come. Drainage ditches and sloughs along the field edges are freshly terraced. Tailwater ponds have been recently carved out of the bare ground to catch sediment before it goes into the adjacent slough. Areas next to the drainage ditch and pond have been planted with shrubs, trees, and a variety of native wild flowers and grasses.

The project is part of a larger effort led by the Xerces Society to promote pollinator conservation in agricultural landscapes. Restoration ecologists from the Xerces Society, the University of California, Berkeley, Audubon California's Landowner Stewardship Project, and the Center for Land-Based Learning have teamed up with local landowners to implement this and other habitat restoration projects tailor-made for crop pollinating native bees. This is the first project of its kind to field test restoration protocols specifically designed to increase wild native pollinators.

Some twenty-five species of trees, shrubs, and forbs have been planted along 1.5 miles of linear habitat to hold on to the soil, shade the streams, and provide abundant pollen and nectar for crop-pollinating bees. The menu of plants was developed based on over four years of research by scientists to identify which native flowers are most commonly used by native crop-pollinating bees.

Audubon California and the Center for Land-Based Learning used their extensive farm-restoration experience to work with farm managers to implement the planting. For these two groups, this project is part of a larger effort to restore watersheds in a way that is beneficial to adjacent farms.

Nest sites are important resources to consider when restoring native bee habitat. Interspersed throughout the habitat, blocks of wood riddled with narrow holes and areas of semi-bare soil provide nesting places for native bee species. Over the next three years, as plants mature and nest sites are colonized, scientists from University of California, Berkeley and the Xerces Society will monitor the changes to local populations of native bees and calculate the dollar value of the increased crop pollination resulting from this restored habitat.

Funding for this project comes from the Natural Resource Conservation Service, the CS Fund, the Richard and Rhoda Goldman Fund, and Gaia Fund.

Text and photograph by Mace Vaughan,
Xerces Society

CREATING BEE NEST SITES

NESTING SITES FOR GROUND-NESTING BEES

Most native bees nest in the ground. The requirements of one species, the alkali bee, are so well understood that artificial nesting sites are created commercially to provide reliable crop pollination for alfalfa in eastern Washington and Idaho.

Unlike the alkali bee, the *precise* conditions needed by most other ground-nesting bee species are not well known. However, the methods below will allow land managers to create conditions suited to a variety of species. Colonization of these nest sites will depend upon which bees are already present in the area, their successful reproduction and population growth, and the suitability of other nearby sites.

Generally, 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. Nest sites that are closer to agricultural fields will provide the greatest pollination benefit.

Maximize untilled 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 untilled. 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. Growers also can look for nest sites that already exist and then do the best they can to maintain these areas.

Semi-bare ground

The most straightforward approach to creating sites for ground-nesting bees is to clear some of the vegetation from a gently sloping or flat area that is not under cultivation. 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.

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.)

Different ground conditions—from vertical banks to virtually flat ground—draw different bee species. After creating several different areas, farmers can observe which sites ultimately attract ground-nesting bees.

Soil piles

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 percent sand). The easiest approach is to pile up soil from the farm, but then to also consider mixing in some sand.

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. Other management tools include spotty herbicide treatments, fire, and mowing. 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.

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

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.)

Nests 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). [Note: if snags do not pose a hazard, keeping them will also provide habitat for birds and other wildlife.] Information about the blue orchard bee is widely available (see Appendix D for recommended books on how to manage this bee). In most places, this bee is active only during the blooming of spring-flowering orchard crops. However, many other species of bees will nest in artificially created wooden blocks with holes drilled in them. 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.

Wooden blocks

A standard, commercially made bee nest is a wooden block with many holes drilled in it. The holes are usually 5/16 of an inch in diameter, the size preferred by blue orchard bees. These blocks are very simple to make, although the blocks sold in stores are often 3 1/2 inches deep—too shallow for blue orchard bees.

To accommodate the needs of the many bee species that are active throughout the summer months it is important to create blocks containing many hole diameters. Preservative-free lumber works well: a 4-by-4 for blocks with holes narrower than 1/4 inch, or a 4-by-6 for blocks with holes wider than 1/4 inch. 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 eight inches high.

In one side, drill a series of nest holes. Each hole should be between 3/32 and 3/8 inch in diameter. Holes 1/4 inch or less in diameter should be between 3 and 5 inches deep. Holes larger than 1/4 inch should be 5 to 6 inches 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

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 Mace Vaughan.)

is worthwhile to create multiple blocks, each block with a different sized tunnel. 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.

The holes in a nest block should be about 3/4 inch 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-inch minimum recommended depth; in this case, holes should simply be drilled as deeply as possible. Bees that use smaller

Nest sites for tunnel-nesting bees can be made in many ways. They may be made from a stack of grooved planks (left photo). Nests also may be constructed from a bundle of hollow stems (right photo), such as bamboo (shown here), common reed, or teasel. (Photographs by Matthew Shepherd and Mace Vaughan.)

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.

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.

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 four feet 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.

Nesting materials

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 likely are already present, but providing a diversity of native plants and some mud puddles may be beneficial.

Maintaining nests for wood-nesting bees

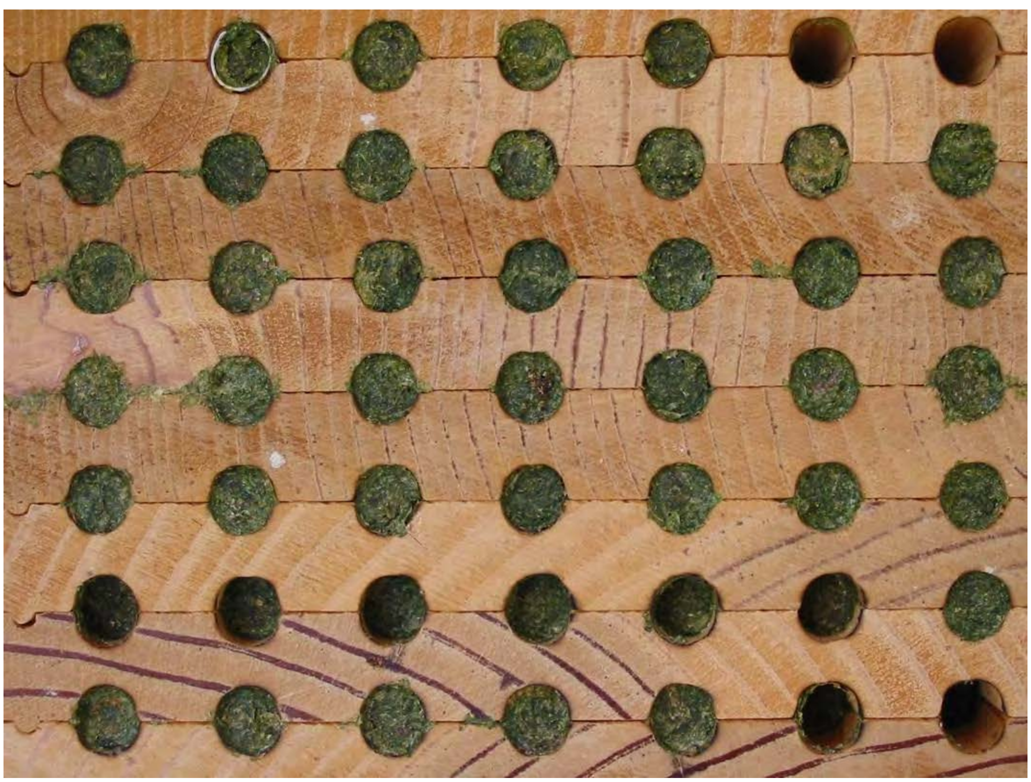
Whether nesting sites are wooden blocks, twig bundles, or other materials, the most significant maintenance issue is whether and when to clean out the holes. In general, cleaning will help to reduce parasites, fungi, and diseases that might affect the developing bees in their brood cells.

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, one inch 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 redrill 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 sin-



When her nest is completed, the wood-nesting female 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.)

gle exit hole, one inch 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 redrill the holes or remove and destroy the blocks. More elaborate ways to rid nest blocks of parasites are described in guides on rearing blue orchard bees (see 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 percent 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 *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.

The grass should be planted in a strip at least five feet 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.

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

Case Study

Jefferson Farm, Oregon

Oak savanna is a wildlife-rich habitat characterized by large, spreading oak trees growing over a flower-rich grassland. Once widespread across Oregon's Willamette Valley, only about one percent of the valley's savanna remains. At Jefferson Farm, a few miles south of Salem, Mark and Jolly Krautmann are restoring 135 acres of oak savanna.

The primary goals of this project are to increase the diversity and abundance of native plants on the project site and to encourage a rich community of savanna-dependent wildlife. Habitat for pollinators is recognized as a key component of this effort.

The project site was heavily degraded by decades of grazing and the growth of dense oak thickets and brush. The thickets and scrub have been cleared by mechanical tree shearing, brush mowing, and hand-cutting, with the aim of returning to the historic density of five to ten oaks per acre. Non-native and invasive weeds were controlled using a combination of broadcast-sprayed and spot-sprayed herbicides.

Beneath the oaks more than fifty species of native wild flowers and grasses are being re-established. The wild flowers are a key source of nectar and pollen for bees and butterflies. The plants also serve as important caterpillar host plants. A variety of seeding methods were used on different parts of the site, including a seed drill, a pull-behind spinner spreader, hydroseeding in steep slope areas, and hand seeding.

Savanna habitat is more than just flowers. Twenty-one large conifer trees have been limbed and topped to create long standing snags in which birds and insects can nest. In numerous places, piles of woody debris were left. Patches of bare ground were also left unseeded, including sites known to harbor ground-nesting bees.

Once initial restoration activities have been completed, there will be constant need for monitoring and management of the project area. Prescribed fire will be the main tool for managing the grasslands. The site will be divided into a series of smaller units burned on a rotation of 3 to 5 years.

Natural areas like this play an important role in farm landscapes. They can serve as an important source of native bees. These pollinators can then visit crops grown on adjacent farms or colonize new habitat created for pollinators in nearby intensively-farmed landscapes.

The Krautmanns have received financial support from federal and state wildlife agencies and engaged a variety of organizations, including U.S. Fish and Wildlife Service, Willamette University researchers, public schools, and community groups.

Text and photograph by Lynda Boyer,
Heritage Seedlings, Inc.

INSECTICIDES AND POLLINATORS

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.

The bumble bee *Bombus ternarius* pollinating blueberry blossoms in eastern Canada. Sixty-seven species of native bee visit these flowers. (Photograph by Steve Javorek.)

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 percent. 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 have been investigated since 1992. 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 EFFECTS OF INSECTICIDES

Foraging bees are poisoned by insecticides when they absorb the fast-acting toxins through the outer "skin" that forms their exoskeleton, drink toxin-tainted nectar, or gather pesticide-covered pollen or micro-encapsulated pesticides. Although the spray or dust will cover and kill significant numbers of bees in the field if they are foraging during insecticide applications, most poisonings occur when bees contact insecticide residues on plants in the hours or days after application. Bees smaller than honey bees, which include the majority of our native bees, have a larger surface area relative to their body size. Because of this, they absorb a relatively higher dose and may be killed by lower concentrations of insecticides coming from spray drift or residues on plants.

The risk of poisoning is not restricted to contact with insecticides in the field. Slow-acting toxins may be carried back to the nest where they are stored with pollen and nectar and eaten by the young bees. Contaminated pollen can remain toxic for up to a year, killing the larvae or, in social species, the other adult bees in the nest.

Leafcutter bees, mason bees, and other solitary bees in the family Megachilidae gather leaf pieces or flower petals to construct brood cells. If these materials are taken from a recently treated field, they too will contaminate bee nests.

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 crop buffers are maintained. (Photograph courtesy of NRCS.)

SUB-LETHAL EFFECTS

Bee kills are not the only impact of insecticides. Sub-lethal doses can affect the behavior of pollinators. Bees exposed to 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 aggressive or agitated behavior, jerky or wobbly movements, or paralysis. These changes in behavior impede foraging and nest building and lead to the premature death of the bee or her offspring.

Sub-lethal doses also can come from direct contact with pesticides or toxins brought into a nest with nectar and pollen and may reduce egg-laying by female bees or inhibit the growth of larval bees.

REDUCING THE NEED FOR INSECTICIDES

Given the damage insecticides inflict upon native 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. Growers can contact local extension offices to learn more about these and other IPM techniques, as well as to learn about organic growing methods for a particular crop.

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* (*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 Riedl et al. (2006). 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.

Application method

Two considerations are appropriate here: droplet size and the potential for drift onto adjacent habitat. 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, apply insecticides from the ground, not from an aircraft, and leave a 25-foot pesticide-free buffer around the edge of the target spray area, or at least as much of a buffer as possible.

If the wind is too calm, this may indicate a temperature inversion. Apply when wind speed is 15 mph or less, wind direction is away from a sensitive area, and use a drift reduction technology if applicable. Do not apply during a temperature inversion, which may be determined by noting the presence of ground fog, light variable wind (below 3mph typically), or layering of smoke and dust.

Formulation

Use formulations that are safest for bees. According to the *Pollinator Protection Handbook*, the insecticide formulations at the top of Table 1 are significantly more hazardous to bees than those toward the bottom.

Micro-encapsulated products (not in Table 1), 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

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.

Temperature and dew

Temperature and dew have a significant effect on the

Table 1. Relative toxicity to bees of different pesticide formulations

Formulation	Toxicity to bees
Dust	Most toxic
Wettable powder	↓
Flowable	↓
Emulsifiable concentrate	↓
Soluble powder	↓
Solution	↓
Granular	Least toxic

(Adapted from Johansen and Mayer, 1990.)

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. Be sure to look at flowers to decide when *all* bee activity has ceased before applying a product (usually after dark). 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. 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 flowers are 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. These tools are very targeted and do not put poisons onto the land. New products continue to be developed

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.)

Case Study

Wind Dancer Farms, Michigan

Blueberries are highly dependent on bees for pollination. Without sufficient pollen transfer between flowers, the fruit can be small and uneven with slow ripening, so most blueberry growers rent hives of European honey bees every year. However, these bees are less effective under the cool, wet weather that occurs sometimes in northern states during blueberry bloom. This makes native bees a highly desirable component of the pollination workforce. At Wind Dancer Farms in Grand Haven, along the shore of Lake Michigan, Richard Rant is implementing pollinator protection strategies to help ensure that native bees will help to fully pollinate his blueberry crop every spring.

One of the first steps was to provide forage for bees before and after blueberry flowers open. Native willow trees are maintained in hedgerows to provide forage for mining and mason bees before the early blueberry varieties bloom. To provide flowers afterwards, the Rants have established white clover in the row middles between the bushes. The clover provides a food source for bees through the year, and has the added benefit of giving nitrogen to the bushes, making it a multifunctional ground cover.

Building the bee's food resources has also coincided with a gradual reduction in the use of insecticides harmful to bees. Six years ago, the fields were treated with seven to eight sprays of broad-spectrum carbamate and organophosphate insecticides to protect the berries from pest insects. Today they receive fewer sprays and most of these are selective, bee-safe products. By enrolling in IPM training classes, learning about more selective insecticides, monitoring fields closely, and only spraying at night, the Rants have saved money and are saving their bees.

Blueberries need plenty of water to be most productive, and so in 2004 the Rants began to excavate a new pond. The resulting sand pile was an opportunity to design and create a pollinator-friendly landscape from scratch. With funding from the NRCS EQIP program to stabilize the sand, and information from Michigan State University research projects to choose appropriate native flowering plants for bees and natural enemies, a new pollinator preserve will soon sit in the middle of their 40-acre blueberry farm. This preserve will contain a mix of shrubs and wild flowers, nesting habitat and the nearby water.

The Rants estimate that twenty to thirty percent of their yield is directly attributable to native bees. With blueberries fetching $1 a pound, this amounts to a $64,000 value on this farm each year. While the time and money invested in pollinator protection can add up, the payback in increased fruit makes sound economic sense for this farm, as well as for the sensitive lakeshore environment where it sits.

Text and photograph by Rufus Isaacs,
Michigan State University

Chapter 9

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 the Colony Collapse Disorder has resulted in significant 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.

Where to find financial or other assistance for conserving pollinator habitat

The USDA's Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) provide financial and technical assistance to support conservation efforts for pollinators and other wildlife on Farms. Conservation programs such as the Environmental Quality Incentives Program, Wildlife Habitat Incentives Program, Grasslands Reserve Program, Wetlands Reserve Program, Conservation Security Program, and Conservation Reserve Program all can be used to help agricultural producers establish pollinator-friendly native species plantings. For information on these conservation programs, contact the local NRCS, FAS, or conservation district office. The office

The yellow-faced bumble bee (*Bombus vosnesenskii*) pollinating red raspberries in Oregon. (Photograph by Mace Vaughan).

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.

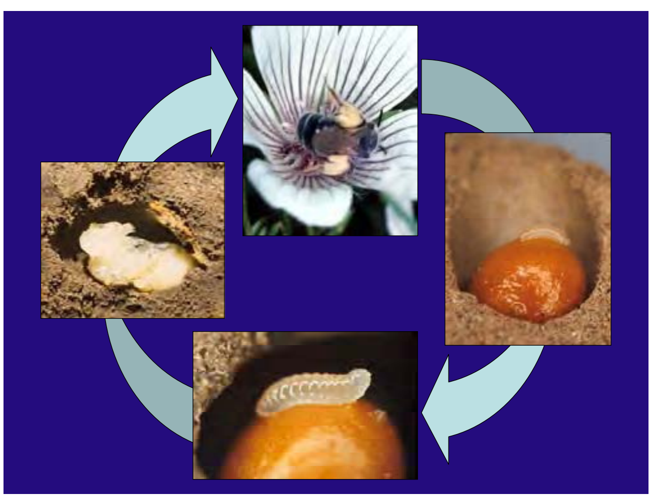
APPENDIX A

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 as food for their offspring and, in doing this, carry large quantities of pollen from flower to flower. Both male and female bees feed on nectar, but only the females gather pollen to take back to her nest. 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. That is how plants are pollinated.

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, 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.



Solitary ground nesting bees, such as this mining bee (*Andrena* sp.), spend about eleven 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.)

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. The life cycle of these bee species is often closely tied to their host plants; the 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, only a few species are in fact social. Social bees live as a colony in a nest and share the labor of building the nest, caring for offspring, and foraging for pollen and nectar. The truly social bees in the U.S. are the non–native European honey bee (*Apis mellifera*) and the bumble bees (genus *Bombus*; about forty-five species), although about two hundred species of sweat bees exhibit some level of social behavior. Nearly all of the rest of the approximately four thousand species of bees in the U.S. 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 eleven 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.

Female native bees have amazing engineering skills, going to extraordinary lengths to construct a secure nest. About 30 percent 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 percent 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 ten 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 leaf or petal, 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. 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 twenty or thirty 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 within a protective cocoon 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 U.S. 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.

Appendix B
Garden Plants for Bees

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, except in the areas within their natural distribution. When choosing plants, avoid hybrid varieties, which were often bred for showy petals at the expense of nectar or pollen production.

Common name	Genus name
Giant hyssop	*Agastache*
Milkweed	*Asclepias*
Borage	*Borago*
Tickseed	*Coreopsis*
Cosmos	*Cosmos*
Purple coneflower	*Echinacea*
California poppy	*Eschscholzia*
Joe-pye weed	*Eupatorium*
Blanketflower	*Gaillardia*
Globe gilia	*Gilia*
Sunflower	*Helianthus*
Hyssop	*Hyssopus*
Purple gay-feather	*Liatris*
Lupine	*Lupinus*
Bergamot (bee balm)	*Monarda*
Basil	*Ocimum*
Marjoram	*Origanum*
Beardtongue	*Penstemon*
Russian sage	*Perovskia*
Scorpionweed	*Phacelia*
Rosemary	*Rosmarinus*
Rosinweed	*Silphium*
Aster	*Symphyotrichum*

APPENDIX C

RESOURCES: XERCES SOCIETY WEBSITE

The Pollinator Conservation Resource Center on the Xerces Society's website includes a wealth of information from Xerces and other leading conservation organizations and agencies. For example, the USDA Natural Resources Conservation Service (NRCS), various state Cooperative Extension programs, and Xerces have all developed region-specific lists of native plants useful for pollinator habitat enhancement efforts. These can all be downloaded from the resource center, http://www.xerces.org/pollinator-resource-center/. Select your region of the country to find those lists, as well as habitat conservation guides, nest management instructions, bee identification and monitoring resources, and a directory of native pollinator plant nurseries.

APPENDIX D

RESOURCES: WEBSITES AND PUBLICATIONS

This appendix lists publications and websites (in addition to the Xerces website) that might be useful for implementing pollinator conservation measures. The focus is on materials that are written for the general public or that are easily available. For example, many of the articles can be found online.

For anyone interested in learning more about the fundamentals of native bee biology, crop pollination, and pollinator conservation, we highly recommend the following books:

- *Attracting Native Pollinators. Protecting North America's Bees and Butterflies* by Mader, Shepherd, Vaughan, Black, and LeBuhn.
- *Bees of the World* by O'Toole and Raw
- *Crop Pollination by Bees* by Delaplane and Mayer
- *The Natural History of Bumblebees* by Kearns and Thomson

WEBSITES

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 web site provides information on identifying bees, bee 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 information on NRCS conservation programs, contact your local NRCS or conservation district office (http://offices.sc.egov.usda.gov/locator/app).

PUBLICATIONS

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Pollinators are essential to our environment. The ecological service they provide is necessary for the reproduction of nearly 70 percent of the world's flowering plants. This includes more than two-thirds of the world's crop species, whose fruits and seeds together provide over 30 percent of the foods and beverages that we consume. The United States alone grows more than one hundred crops that either need or benefit from pollinators. The economic value of insect-pollinated crops in the United States was estimated to be $20 billion in 2000. Native insects were responsible for pollinating an estimated $3 billion of this total.

With the steady decline in the number of managed honey bee colonies, most recently from the Colony Collapse Disorder, 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 do just that.

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.

Persephone Farm in Lebanon, Oregon provides a haven for crop-pollinating native bees. Flower rich hedgerows, bolting crops, insectary plantings, adjacent natural areas, and power line right-of-ways all provide important nectar, pollen, and nest sites that help these bees to thrive. (Photograph by Paul Jepson.)

Front cover

Native bees provide a vital service to farmers across the country. Here, a native sunflower bee (*Svastra* sp.) pollinates a sunflower in California's Central Valley. Research on this crop has demonstrated that native bees can double the effectiveness of honey bees by causing them to move more often between rows of flowers. (Photograph by Sarah Greenleaf.)

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