Native Pollinators

HOW TO PROTECT AND ENHANCE HABITAT FOR NATIVE BEES

| Mace Vaughan and Scott Hoffman Black

ABSTRACT

The success of all restoration efforts—and indeed, of life as we know it—depends on a healthy and diverse population of native pollinators. Pollinators are critical for seed production and the perpetuation of native plants (and our food crops). Bees are our most important pollinators in North America. Nursery managers, seed producers, and field restorationists can protect and enhance habitat for native bees. Native bees have 3 basic habitat needs. 1) Bees need a constant supply of food—a diversity of plants with overlapping blooming times so flowers are available throughout the growing season. 2) Bees need places to nest. Most native bees are solitary, and none build wax or paper structures like we associate with honey bees or wasps. Most bees nest in small warrens they construct underground, or in narrow tunnels often left behind by beetle larvae in dead trees. Bumble bees require small cavities, either in tree boles, underground (often in old rodent burrows), or under clumps of fallen grass, in which to raise their young, as well as undisturbed duff in which queens burrow and hibernate through the winter. 3) Bees need protection from most pesticides. Insecticides are primarily broad spectrum and are therefore deadly to bees. Indiscriminate herbicide use can remove many of the flowers that bees need for food. Foster bees by observing, protecting, and enhancing nesting sites and year-round sources of pollen and nectar.

Vaughan M, Black SH. 2008. Native pollinators and nurseries: how to protect and enhance habitat for native bees. Native Plants Journal 9(2):80–91.

KEY WORDS

bumble bees, honey bees, wood-nesting bees, ground-nesting bees

Seed production, nursery, and restoration practices can provide essential habitat for bees, our most important pollinators. Between 60 and 80% of the world's 250 000 flowering plants require a visit from an insect pollinator to be most productive. Formerly, native bees and feral honey bees met the pollination needs of many growers, when farms were small, diverse, and often adjacent to areas of habitat that harbored important pollinators. As farms became larger and nearby habitat to support native pollinators diminished, many producers began to rely on introduced European honey bees to ensure adequate pollination services. Even so, the number of managed European honey bee hives is half of what it was in the 1950s and continues to decline, primarily because of diseases, parasites, and, since 2006, Colony Collapse Disorder. Native bees, however, significantly contribute to crop pollination—and, in some cases, provide all the pollination. It is important to diversify and support the native pollinators upon which we rely.

Intensively managed landscapes and newly restored sites often lack the abundance and diversity of forage and nesting sites that native bees require. By providing nesting sites, pollen and nectar

Figure 1. With the ongoing decline of introduced European honey bees, it is essential to diversify and support the native pollinators upon which we rely, such as this native bumble bee (*Bombus melanopygus*) visiting black capped raspberry (*Rubus* spp. [Rosaceae]) flowers. Photo by Mace Vaughan, The Xerces Society

Figure 2. A sweat bee on Pacific ninebark (*Physocarpus capitatus* (Pursh) Kuntze [Rosaceae]) flowers. Native bees come in all shapes and sizes. Most native bees are unlikely to sting. (Yellowjackets and wasps are not bees, nor are they significant crop pollinators. Wasps are, however, fantastic predators of soft-bodied insect pests.) Photo by Mace Vaughan, The Xerces Society

sources, and protection from pesticides, a diverse community of native bee species will increase. With such an increase, adjacent crops may yield more, growers could rely less on imported European honey bees, and biodiversity and other wildlife species would benefit. Enhancing bee populations in new restoration plantings can help newly established plants produce more progeny to fully occupy the site. Demonstration gardens and public relations can also benefit from raising awareness about native pollinators. All nurseries, particularly forb seed producers, have many opportunities to protect and enhance bee habitat in and around production areas. This article discusses how nurseries, seed producers, and restorationists can support crop-pollinating bees as part of good management (Figure 1). Other floral visitors, such as butterflies or the wasps and flies that feed on pests, seldom pollinate crops but will benefit from some of the techniques below.

THE DIRT ON NATIVE BEES

Bees—both European honey bees and native bees—are the most important pollinators of insect-pollinated crops in the US. Bees are superior, and frequently the only, pollinators because they transport pollen and typically visit flowers from a single plant species during each foraging trip, which ensures that the correct pollen is transferred from plant to plant. Bees also forage out from a central nest and therefore stay in a specific area, pollinating plants as they bloom.

Although this article pertains to all bees, the emphasis is on providing habitat and forage for unmanaged native species rather than the European honey bee. Hundreds of species of native bees provide a free and valuable pollination service (Figure 2). Some native bee species, such as mason and bumble bees, are active when conditions are too cold and wet for honey bees. In general, native bees are more versatile than honey bees. For example, some native species buzz pollinate flowers, which honey bees cannot do; this vibration releases pollen from deep inside the anthers of certain flowers, such as species of native cranberry, blueberry, and huckleberry (*Vaccinium* spp. L. [Ericaceae]), resulting in larger and more abundant fruit.

IMPROVING FORAGE FOR NATIVE POLLINATORS

One of the best ways to attract and support a healthy pollinator population is to ensure a rich, diverse plant community. Seed production areas can help provide this source of pollen and nectar, while areas adjacent to crops can be enhanced to offer forage in times when crops might not be in flower. Areas in and around nursery production sites can also be protected

and enhanced for pollinators. Restoration practices can ensure that a constant food supply is available to support pollinators on project sites. In return, an abundance and variety of insect pollinators will yield a more fertile, productive, and self-perpetuating landscape.

Step 1:
Identify and Protect Bee Forage Already in Place

Existing pollen and nectar sources can often be found within production areas as well as near fencerows or hedgerows, riparian buffers, other natural areas, or any place on or around the nursery site where a variety of plants (weeds or otherwise) grow. To identify good forage plants, observe flowers in the morning and in the middle of the day to note how intensively each species is visited by bees and other insects (Figure 4). Honey bees and bumble bees are both good, recognizable indicators of flowering plants that other native bees will use. Try to protect these sites and their flowering plants.

Step 2:
Ensure That Flowers Are Present throughout the Growing Season

Bees are most active from February to November, longer in mild climates. The social bumble bee is often seen in any of these months, whereas the emergence and short (4 to 6 wk) active adult life of many solitary-nesting bees depends on the species and can occur from early spring to late summer. Therefore, a sequence of plants that provide a diversity of flowers throughout the growing season is necessary to support a diverse community of native bee species.

Bumble bees are some of our most efficient crop pollinators. When forage is available early in the growing season (such as willow, red bud, maple, or manzanita), freshly emerged, overwintering bumble bee queens are more successful in establishing their colonies. Also, some solitary bees produce multiple generations each year, so reproductive success in the spring and early summer can lead to larger populations in the mid- to late-summer, when many crops are in bloom.

Remember to include plants that bloom in the fall. When plants such as goldenrod and asters are in bloom, some native bee species, as well as honey bees, will benefit from the abundant late-season forage. For example, the next year's bumble bee queens will be able to go into hibernation with more energy reserves than they would otherwise. If seed production practices don't provide continuous forage for bees from spring through fall, consider establishing forage plants on boundaries, as ground covers, or in other areas to supplement.

Step 3:
Identify the Best Sites to Enhance Forage

In addition to crop plants and production areas, identify the best sites to enhance forage. Conservation practices provide unique opportunities to enhance nectar and pollen sources and nesting sites for crop-pollinating bees. For ground cover between crop rows or in fallow areas, legume forage will not only fix nitrogen but also provide nectar and pollen for bees. Diverse native forbs and shrubs may be planted in rows for pollinators if feasible. Riparian buffers are excellent locations to incorporate early flowering willows, as well as shrubs and forbs that require more water than is naturally available elsewhere.

Windbreaks and hedgerows, by design, reduce wind velocity in adjacent fields. Windbreaks provide places to plant flowering trees and shrubs and other blooming perennials close to fields. Make a special effort to include flowering forbs on the margins of the windbreak or hedgerow. The area between the trees could also be used for beneficial forbs during the establishment period of the windbreak. Many bare-

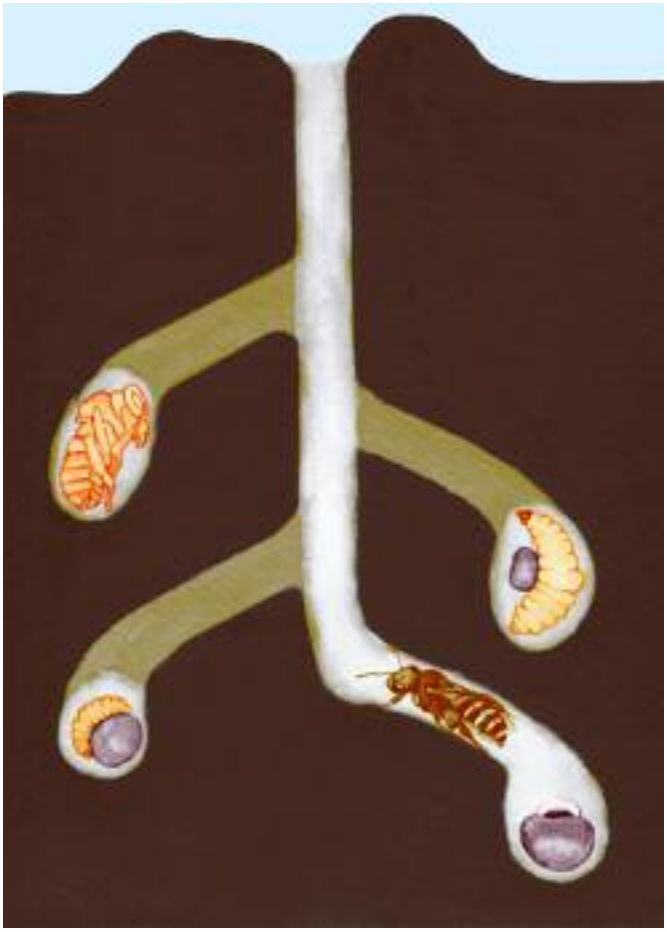


Figure 3. Solitary ground-nesting native bees spend most of the year growing through the egg, larval, and pupal stages while hidden in their nest cells underground. Don't worry if native bees nest close to work areas. Solitary bees are gentle and very reluctant to sting. Bumble bees are not aggressive unless their nests are exposed or they are harassed. If we respect their needs, they will ignore us.

Illustration courtesy of Sarina Jepsen, The Xerces Society

root nurseries are planting windbreaks of native shrubs as locally adapted seed sources for future seedling production—paying attention to bee forage in these areas could reap dividends (Figure 5).

Other sites, such as existing natural habitat, field and road edges, drainage ditches, land around buildings, and fields that are too wet or too dry for crop production, also provide convenient, under-utilized places to cultivate bee forage.

Step 4: Identify the Best Plants

Wherever possible, consider how to include plants, shrubs, and trees that, together, produce abundant flowers throughout the growing season. Locally native plants with a diversity of flower shapes, sizes, and colors will support the greatest variety of crop pollinators.

Step 5: Plan Ahead to Ensure Successful Installation and Maintenance

Make sure that nursery staff, neighbors, and county road and electric crews know about the habitat. Signs help educate others about what is happening at the nursery and, potentially, encourage others to do similar work. Minimizing use of herbicides and pesticides is also essential to ensuring bee survival.

ENHANCING NEST SITES FOR NATIVE BEE CROP POLLINATORS

In addition to nectar and pollen for food, bees need nesting sites. Depending on nursery practices, some native bees may be able to nest in or between crop rows. In other cases, adjacent areas can help provide nesting sites.

Where Do Native Bees Nest?

Native bees have very different nesting requirements from the more familiar European honey bee (introduced from Europe in the early 1600s). Unlike the large comb-filled hives of a honey bee colony, native bees are generally solitary species, with each female constructing and provisioning the nest by herself. Only when adults emerge from their hidden nests do we see them flying about pollinating crops and other plants. The rest of the year they are tucked away inside the cells of their underground or plant-tunnel nests (Figure 6; also see Figure 3). Most solitary bees are active as adults for only a few weeks each year, and most have only a single annual generation. Exceptions are some social sweat bees that can have several overlapping generations through the summer. These sweat bees are the most abundant native bees in some studies of crop pollination and build large populations over the summer growing season.

Solitary wood-nesting bees

About 30% of our 4000 native bee species are solitary wood-nesters that build their nests inside hollow tunnels. These tunnels may occur in the soft pithy centers of some

Figure 4. A bumble bee pollinates a rabbitbrush (*Chrysothamnus* sp. Nutt. [Asteraceae]) flower. Photo by Mace Vaughan, The Xerces Society

Figure 5. Windbreaks help reduce winds, making it easier for pollinators to fly and visit flowers. Less wind creates slightly elevated temperatures around plantings, which increases the time that pollinators can be active. Finally, research shows that windbreaks and other linear plantings can serve as buffers to drifting pesticides, which helps protect pollinators from chemicals used in adjacent fields.
Photo by Thomas D Landis

WHAT DO BEES NEED?

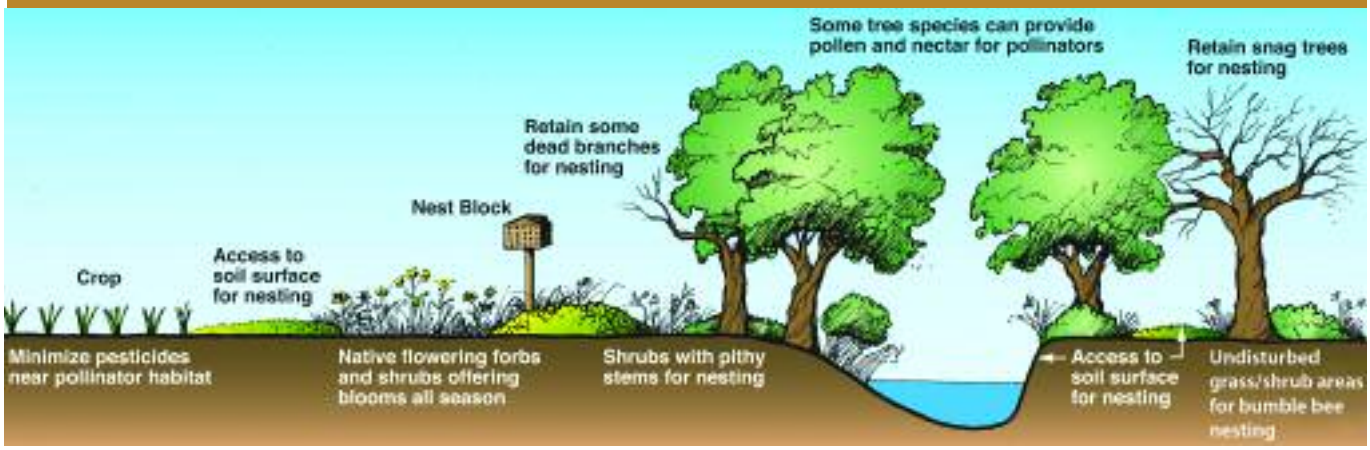


Figure 6. Most native bees nest underground in areas that are sunny, well-drained, and either bare or partly vegetated. Alternatively, they nest in narrow tunnels in wood or in small cavities such as abandoned rodent nests. Illustration courtesy of USDA National Agroforestry Center

twigs (for example, box elder, elderberry, or various cane berries) (Figure 7); they may be left behind by wood-boring beetle larvae or, in the case of carpenter bees, may be excavated by the bees themselves. Another small but important set of bee species, at least one of which has been documented as an important pollinator of watermelon, tunnel into soft, aboveground rotting logs and stumps.

Solitary ground-nesting bees

Most (about 70%) of our native bee species excavate their nests underground. These ground-nesting native bees all burrow narrow tunnels down to small chambers (the brood cells) that are 15 to 91 cm (6 to 36 in) or more under the surface. Inside these brood cells next year's bees develop. To build these nests, most bees need direct access to the soil surface, often on sloped or well-drained sites (Figure 8).

Bumble bees

The remaining bees—only about 45 species in the US—are social bumble bees. Bumble bees are frequently our most effective crop pollinators. They construct nests in small cavities, often in old rodent burrows, either underground or beneath fallen plant matter, or occasionally aboveground in abandoned bird nests (Figure 9). Queen bumble bees start new nests each spring and by midsummer their colonies can have dozens or hundreds of workers, all visiting nearby flowers. For this reason, doing what you can to encourage bumble bee nest sites in and around the nursery can go a long way toward supporting plants that flower during summer months.

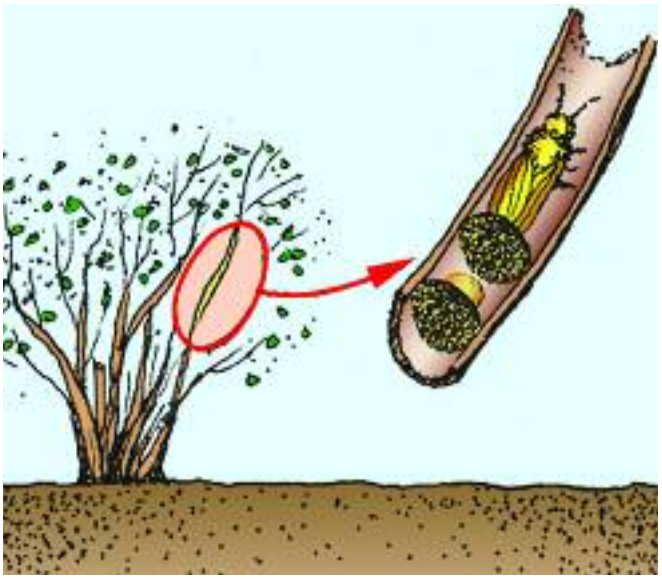


Figure 7. Example of where solitary wood-nesting bees live.
Illustration courtesy of USDA National Agroforestry Center

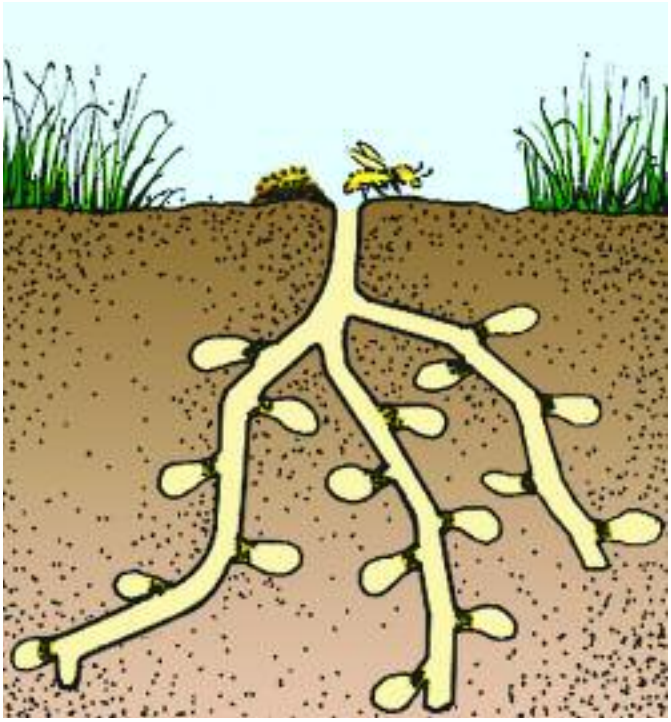


Figure 8. Example of where solitary wood-nesting bees live.
Illustration courtesy of USDA National Agroforestry Center

Figure 9. Example of where bumble bees live.
Illustration courtesy of USDA National Agroforestry Center

Protecting Nest Sites

The easiest approach to supporting native bees in a landscape is to look for potential nesting areas and then to protect them as best as possible. In and around nursery operations are many potential nesting opportunities for native bees. Specifically:

- Native bee nests may be found in cultivated fields, even in seed and plant production areas. Native bee nests have been found in orchards, front yards, and along country roads. Protect sloped or well-drained ground sites where plants are sparse and direct access to soil is available. These are the areas where ground-nesting bees may dig nests.
- Leave some areas untilled and minimize weed control tillage. Turning the soil destroys all ground nests that are present at that depth and hinders the emergence of bees that are nesting deeper in the ground.
- Protect grassy thickets, or other areas of dense, low cover from mowing or other disturbance. These are the sites where bumble bees might find the nest cavities they need, not to mention biennial or perennial forbs that can provide significant food resources.
- Retain dead or dying trees and branches whenever it is safe and practical to do so. Wood-boring beetle larvae often fill dead trees and branches with narrow tunnels into which tunnel-nesting bees will move. In addition, retain rotting logs where some bee species may burrow tunnels in which to nest.

Enhancing Nest Sites in the Field

The following active management techniques may be employed to further increase nesting opportunities.

Solitary wood-nesting bees

- Using a hand drill and a variety of drill bit sizes (from 3/32 in [3 mm] to 5/16 in [9 mm]), drill holes as deep as possible into downed dry wood sections.
- Erect the section upright like a fence post to simulate a beetle-tunneled snag. A variety of hole diameters will support a variety of different sized bee species. Face the holes south as much as possible.
- Using the same drill and bits, drill holes in stumps or standing dead wood, so long as the wood is not rotting or saturated with water. Angle the holes slightly upward to reduce water entry.
- Plant shrubs or other plants that have pithy stems. Every year, cut back some of the new growth to expose the pithy interior of the stems. Elderberry, boxelder, blackberries or raspberries (*Rubus* spp. L. [Rosaceae]), sumac, or dogwood are all good choices.

Solitary ground-nesting bees

The precise conditions—soil type, soil texture, degree of compaction, and moisture retention—needed by most ground-nesting bees is not well known. The methods below, however, could support a variety of species. Colonization of these nest sites will depend on the bees already present in the area, their successful reproduction and population growth, and the suitability of other nearby sites.

- Wherever possible, avoid turning over soil. Bees need stable soil, and their progeny spend up to 11 mo of the year underground. The more surface area left untilled, the more likely bees will find and colonize appropriate nest sites.
- Clear some of the vegetation from a gently sloping or flat area. The goal is to remove thatch, making it easier for bees to access the soil below but still leaving some clumps of grass or other low-growing plants to prevent erosion. The site should be well drained, in an open, sunny place, and, preferably, on a south-facing slope. Different ground conditions, from vertical banks to flat ground, will draw different bee species, so create a variety of partially bare patches and observe which ones best attract ground-nesting bees.

Bumble bees

Studies indicate that bumble bees often occupy the grassy interface between open fields and hedgerows or woods. This has been attributed to the presence of abandoned rodent nests in which bumble bees nest. Areas of habitat suitable for bumble bees should include a mix of native grasses and forbs abutting shrubs or trees. The grass area needs to be at least 1.5 m (5 ft) wide and mowed only every 2 or 3 y. Always mow in the late fall or winter, after the colonies have died for the year and when queens are dormant.

With a few simple tools and minimal resources, nests for bees can be built in and around production areas to provide homes for native bees.

Solitary wood-nesting bees

Tunnel nesters will use a variety of structures that mimic beetle holes in wood or the centers of pithy stems. Simply drill holes in blocks of wood (Figures 10 and 11), or tie a bundle of paper straws or hollow stems together (Figure 12). Include a range of hole sizes to attract a variety of different bees that are active at different times in the year. Mount these blocks with tunnels oriented horizontally in a location that receives morning sun but that has some protection from rain and the extremes of midday sun and heat in the summer. Generally, erect nests at least 1.2 m (4 ft) above the ground.

Figure 10. A backyard nest box for wood-nesting bees. Larger hole diameters (> 0.6 cm [1/4 in]) should be at least 13 cm (5 in) deep. Photo by Mace Vaughan, The Xerces Society

Figure 11. Example of a larger nest box in a sunflower field. Photo by Katharina Ullmann, The Xerces Society

Figure 12. Bamboo bundles for bees in the rafters of a building.
Photo by Mace Vaughan, The Xerces Society

Figure 13. Example of a bumble bee box under a shrub (A). View of cotton packing inside the bumble bee box (B). For more detailed instructions on how to construct artificial nests for all bee types, visit the Xerces Society website, URL: http://www.xerces.org or order the Pollinator Conservation Handbook. Photos by Matthew Shepherd, The Xerces Society

Solitary ground-nesting bees

Create a stable pile of soil, at least 60 cm (2 ft) high, perhaps after excavating ditches or ponds, or grading fields. Different species of bees nest in different soil types, but the soil should be at least 35% sand. If necessary, contain the pile with walls of lumber or bricks. Experiment by creating piles with different soil mixtures or by placing piles in locations that receive different amounts of sun.

Bumble bees

Bumble bees may move into small boxes (cubes 18 cm [7 in] on a side) packed lightly with upholsters' cotton and with a 2-cm (0.75-in) entrance hole (Figure 13). It is important to note, however, that even under the best conditions, only about 5 to 25% of nest boxes may become colonized.

Other Considerations for Successful Nesting

Besides the basic nest structures or features needed by native bees, a few other resources are important for successful nesting.

- Different bee species—particularly tunnel-nesting solitary bees—need various materials to construct their brood cells and seal their nests. A few bees secrete a cellophane-like substance to protect their brood cells, but most use gathered materials such as pieces of leaf or flower petals, mud, fine pebbles, or tree resins. Most likely these materials are already present, but providing a diversity of native plants and creating or protecting areas with damp clay will help.
- Bumble bee queens need protected sites in which to overwinter. These often occur in the soft humus, leaf litter, or other sites protected from extreme winter weather into which they can burrow.
- A bee's nest is a home base from which to scour the surrounding landscape for nectar and pollen. It is important to provide all of the nectar and pollen that bees need. The closer nest sites are located to pollen and nectar sources, the less energy female bees need to spend commuting back and forth, and the more resources they can put into their offspring. As a result, they will produce more offspring, and their populations will grow over time. In addition, if nest sites are located close to abundant nectar and pollen (within 250 m [820 ft]), the bees are less likely to forage where they may encounter insecticides or other hazards that are outside of a grower's control.

Figure 14. This "no spray" sign, along the edge of an organic farm outside Salem, Oregon, is recognized by the Oregon State Department of Transportation. Well-identified "no spray" areas provide a safe haven, free from pesticides, for wild bees to nest and forage. Signs also inform neighbors, workers, and visitors of the need to avoid practices that could kill desirable bees. Photo by Brian Baker, Organic Materials Review Institute, Eugene, Oregon. Used with permission.

PROTECTION FROM PESTICIDES

Pesticides are tools commonly used to control weeds and pest insects. Pesticide use, however, must be balanced against the importance of maintaining healthy populations of crop pollinators that can be damaged by pesticide applications. Good nursery practices together with best management practices for herbicide and pesticide use can help to reduce the unwanted side effects of pesticides and provide a refuge for native pollinators (Figure 14).

Both insecticides and herbicides can be harmful to bees. While herbicides don't directly target pollinators, they can destroy plants that provide flowers when crops are not in bloom, forcing bees to forage more widely for food. This requires more energy and exposes them to more threats, and as a result, they produce fewer offspring to emerge the following year.

Insecticides target insects and, depending on the active ingredient and how it is formulated and applied, have a wide range of toxicities to bees. Foraging bees are poisoned by insecticides when they absorb the fast-acting toxins through their exoskeleton, drink toxin-tainted nectar, or gather polluted pollen or micro-encapsulated insecticides. Slow-acting toxins may be carried back to the nest where they are stored with pollen and nectar and are later eaten by larval bees. Even sublethal doses of insecticides can eventually kill bees by affecting their behavior. Bees that are exposed may have trouble navigating their way back to the nest after foraging, or they may simply be unable to fly.

Whenever feasible, consider non-pesticide solutions first. If the pest level has reached an economic threshold and pesticides must be used, best management practices can help minimize their risk to pollinators. Herbicide impact can be reduced by spot-treating only truly noxious weeds, while protecting other flowering plants. For insecticides, impact can be reduced by carefully selecting active ingredients, formulations, and specificities that are less harmful to bees. Choose application methods that minimize drift, and schedule applications for times of year or at least times of the day when bees are less active, such as after dark.

CONCLUSION

Techniques to protect and enhance forage and nesting sites for native pollinators will help increase the diversity and abundance of pollinators. The result is likely to help plant pollination, seed production, and the long-term perpetuation of native plants on newly restored sites. One or more of these techniques can be easily incorporated into existing nursery, seed production, and restoration practices. Enhancing pollinator habitat is an opportunity to educate staff, clients, landowners, and the surrounding community about the value of bee habitat for the ecosystem and for the bottom line.

ADDITIONAL INFORMATION

Available from the **USDA National Agroforestry Center (NAC),** an organization that accelerates the application of agroforestry through a national network of partners: Contact UNL–East Campus, Lincoln, Nebraska 68583-0822; telephone 402.437.5178; fax 402.437.5712; URL: http://www.unl.edu/nac.

AF Note 32: Vaughan M, Black SH. 2006. Agroforestry: sustaining native bee habitat for crop pollination. USDA National Agroforestry Center.

AF Note 33: Vaughan M, Black SH. 2006. Improving forage for native bee crop pollinators. USDA National Agroforestry Center.

AF Note 34: Vaughan M, Black SH. 2006. Enhancing nest sites for native bee crop pollinators. USDA National Agroforestry Center.

AF Note 35: Vaughan M, Black SH. 2006. Pesticide considerations for native bees in agroforestry. USDA National Agroforestry Center.

A THREE-STEP APPROACH TO ENHANCING HABITAT FOR NATIVE BEES

1. Observe

Observing pollinators and their habitat can be instructive. Try to identify plants that support the most bees. Observe flowers during sunny times of the day and watch for bumble bees and other insects. Also, look for bumble bee nests or in-ground nests of solitary bees. To find these sites, search for holes in the ground or bees flying low as if looking for something besides flowers.

In seed production areas, many pollinators might be observable on the various crops. In addition, places not directly part of nursery production may be providing some habitat needs for pollinators. These areas might include fallow fields; natural areas; gardens; edges of ponds, ditches, fields, and roads; forests; and temporary bee pastures (for example, where inexpensive seed such as alfalfa, canola, or clover has been planted specifically for bees or wildlife). Many conservation practices naturally provide habitat for bees. For example, riparian buffers, hedgerows, and windbreaks probably already include bee-pollinated plants, stable untilled areas for ground nests, snags and pithy stems for tunnel-nesting solitary bees, and cover for bumble bee colonies. Ground cover areas, or stable ground with patchy bare areas, should be checked.

2. Protect

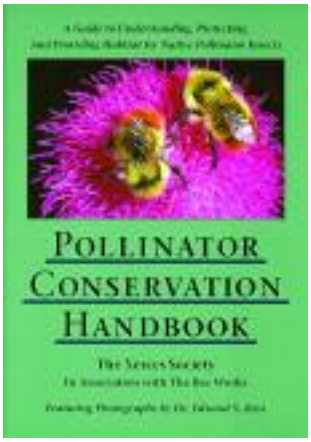
Once you know where bees are living and foraging, try to protect these resources from damaging disturbance and pesticides. For example, avoid tilling the surface during bloom and only till deeply when it is absolutely necessary; never apply insecticides to plants in flower; consider establishing a 15-m (50-ft) perimeter buffer of unsprayed crop area or carefully scout fields to apply insecticides only where they are needed; apply herbicides in the most targeted way possible (spot spraying), and leave snags whenever they do not pose a hazard.

3. Enhance

To enhance habitat for native bee communities, increase the diversity and abundance of flowering plants growing on a site and add nesting habitat. Consider pollinator needs when choosing plants for ground covers, windbreaks, riparian buffers, ornamental/landscaping uses, and other operations. Erecting bee blocks and (or) removing vegetation or thatch from small patches of sunny, south-facing, well-drained soil will increase the likelihood of bees.

Available from the **Xerces Society for Invertebrate Conservation,** an international, nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat: Contact 4828 SE Hawthorne Boulevard, Portland, Oregon 97215; phone 503.232.6639; fax 503.233.6794, URL: http://www.xerces.org.

Black SH, Hodges N, Vaughan M, Shepherd M. 2008. Pollinators in natural areas: a primer on habitat management. Portland (OR): Xerces Society for Invertebrate Conservation. 8 p. URL: http://www.xerces.org/Pollinator_Insect_Conservation/Managing_Habitat_for_Pollinators.pdf



Shepherd M, Buchmann S, Vaughan M, Black S. 2003. Pollinator conservation handbook. Portland (OR): The Xerces Society. 145 p. Xerces Society Pollinator Program, URL: http://www.xerces.org/Pollinator_Insect_Conservation/

Vaughan M, Shepherd M, Kremen C, Black S. 2007. Farming for bees: guidelines for providing native bee habitat on farms, 2nd edition. Portland (OR): Xerces Society for Invertebrate Conservation. 44 p. URL: http://www.xerces.org/Pollinator_Insect_Conservation/Farming_for_Bees_2nd edition.pdf

Other Good Resources

Johansen C, Mayer D. 1990. Pollinator protection: a bee and pesticide handbook. Cheshire (CT): Wicwas Press. 212 p.

Kremen C, Williams NM, Aizen MA, Gemmill-Herren B, LeBuhn G, Minckley R, Packer L, Potts SG, Roulston T, Steffan-Dewenter I, Vázquez DP, Winfree R, Adams L, Crone EE, Greenleaf SS, Keitt TH, Klein A-M, Regetz J, Ricketts TH. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecology Letters 10(4):299–314.

Logan Bee Lab website, URL: http://www.ars.usda.gov/Main/site_main.htm?modecode=54-28-05-00 (Click on the "research" button and look for links to nest blocks and stick nests).

Riedl H, Johansen E, Brewer L, Barbour J. 2006. How to reduce bee poisoning from pesticides. Corvallis (OR): Oregon State University. PNW 591. URL: http://extension.oregonstate.edu/catalog/pdf/pnw/pnw591.pdf.

ACKNOWLEDGMENTS

This article was compiled by Kim M Wilkinson based on Agroforestry Notes 32, 33, 34, and 35 produced by the National Agroforestry Center in cooperation with the Xerces Society. Kimberly L Stuhr of the National Agroforestry Center facilitated permissions. Original illustrations were colorized by Jim Marin Graphics. Thanks to James Cane, USDA ARS; Gretchen LeBuhn, San Francisco State University; T'ai Roulston, University of Virginia; Blair Sampson, USDA ARS; Matthew Shepherd, Xerces Society; Connie Stubbs, University of Maine; Robbin Thorp, University of California, Davis; Neal Williams, Bryn Mawr College; Tom Landis, Nursery Specialist and Consultant; and Brian Baker, PhD, Organic Materials Review Institute.

AUTHOR INFORMATION

Mace Vaughan
mace@xerces.org

Scott Hoffman Black

Xerces Society for Invertebrate Conservation
4828 SE Hawthorne Boulevard
Portland, OR 97215